

MIOCENE MOLLUSKS FROM BOWDEN, JAMAICA

BY

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MIOCENE MOLLUSKS FROM BOWDEN, JAMAICA

PART II, GASTROPODS AND DISCUSSION OF RESULTS

BY WENDELL P. WOODRING

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INTRODUCTION

This report is a continuation of Publication 366, issued in 1925, which contains an account of the fossil-bearing beds at Bowden, Jamaica, and descriptions of the pelecypods and scaphopods found there. The description of the gastropods, here presented, completes the account of the mollusks of the Bowden formation. In addition, a general account of the fauna, its ecologic significance, age, and relations to Miocene faunas in other parts of the world are given. The Pyramidellidae and Melanellidae, comprising about 47 species, are omitted in the descriptions of species, as it is expected that they will be included in a report on the mollusks of these two families from Bowden and other Caribbean fossil localities to be prepared by Dr. Paul Bartsch, of the United States National Museum.

The examination of the gastropods was begun at Johns Hopkins University in 1916. After many interruptions the work was completed under an informal cooperative agreement between the United States Geological Survey and the Carnegie Institution of Washington.

Six collections of Bowden fossils were examined during the preparation of this report. Two of these collections—the Duerden and Aldrich collections—are at Johns Hopkins University. Types and figured specimens from these collections were deposited by Professor Berry in the United States National Museum. Three collections are at the United States National Museum—the Guppy, Bland, and Henderson collections. The Henderson collection is the only large one of these three. The sixth collection, which was only partly examined, is at the Philadelphia Academy of Natural Sciences. Under the description of the species generally only the collection that contains the largest number of specimens is mentioned, without inferring, however, that the species is unrepresented in the other collections. More complete data are given for the species of which the representation in the different collections is markedly discrepant.

The proportion of new species among the gastropods is very much larger than among the pelecypods, principally because the parts of Dall's "Tertiary Fauna of Florida" dealing with the gastropods was limited to a much narrower field than the parts dealing with the pelecypods, and because at that time Dall had at his disposal no large collections of Bowden fossils. Guppy described most of the large species, but the small species were for the most part untouched.

At first it was planned to figure all the species, whether they were named or not. As the work progressed it became apparent that the

expense of figuring so much unnamed material was unwarranted. Therefore, some of the unnamed species are figured and some are not. Most of the unnamed species are new and many of them are represented by material that, if found elsewhere, would be considered suitable to serve as type material. In view of the perfect preservation of the bulk of the Bowden mollusks, I have refused, with few exceptions, to designate as type material very imperfect specimens or shells that clearly are immature. As additional barrels of Bowden fossils are sorted these unnamed species will be found to be represented by more perfect specimens, and additional species will turn up, for every large collection has a number of species unrepresented in any other collection.

The measurements were made with a caliper rule reading to tenths of a millimeter. If the dimensions of illustrations fail to agree with measurements in the text, it means that the enlargements are not precise or that the shell was tilted a little when photographed.

The term "nucleus" used in the description of the gastropods refers to the part of the shell from the apex to the beginning of adult sculpture or to a change in the texture or color of the shell when sculpture is absent. It embraces the whorls formed in the egg case, called "embryonic" whorls by some writers, and also the "nepionic" whorls, or part of a whorl, intervening between the "embryonic" and adult whorls. "Nucleus" is an unsatisfactory term and it has been used by some writers to refer only to the apical whorl. "Protoconch" is a more satisfactory term and its use in nautiloids and ammonoids seems to be no valid objection to its use in gastropods also. "Nucleus" or "nuclear whorls" is adopted because "post-nuclear" is a convenient term for the remaining whorls. "Post-protoconch" is unwieldy and "conch," the corresponding term in nautiloid and ammonoid terminology, is objectionable when applied to gastropods.

Comparisons with foreign Miocene species are deliberately omitted, not because none of the Bowden fossils are similar to foreign species, for many of them are, but because it seems advisable first to describe the American species and then to attempt to compare them with the foreign ones. At the present time even generic comparisons are none too certain, unless large reference collections are available.

The arrangement of families is the same as in Pilsbry's "Revision of W. M. Gabb's Tertiary Mollusca of Santo Domingo" (Proc. Acad. Nat. Sci. Philadelphia, vol. 73, pp. 305-435, 1922). Though this arrangement proceeds from the most "specialized" gastropods to the simpler ones—the reverse order of that followed in the pelecypods—

it is the one generally in use in American literature, and the collections at the United States National Museum are arranged in this order.

Those who have attempted a monographic account of a large fauna will be lenient toward the errors and other shortcomings that will be found in this report. Many early designations of the types of genera were overlooked in the preparation of Publication 366. Omissions of nomenclature relating to this field probably will be found in this report, for it will be a long time before the earliest subsequent designations are gleaned from the literature. I also can not pretend to have covered the literature dealing with the families and genera represented in so large a fauna. Despite the attempt to consider all the Tertiary and Recent described species from the West Indian and adjoining regions, some recorded species may have been overlooked or misinterpreted, and some of the new species may turn out to be synonyms, particularly of living species.

In the treatment of a few features this report differs from Publication 366. In order to make available ready verification, complete references are given for subsequent designations of the types of genera. Also references are given for fossils with which the Bowden species are compared, but not for Recent species, illustrations of most of which can readily be found in manuals. Original descriptions of species are omitted to save space and also because they are unimportant. Formal descriptions are cut down to a minimum and only specific characters are emphasized, as generic characters are described in a brief diagnosis under each genus.

It should be remembered that all the specimens are from the one locality described on pages 7 to 8 of Publication 366, and that this locality is not repeated under the descriptions of the species.

As before, I have had the benefit of advice and assistance from the late Dr. W. H. Dall, Dr. Paul Bartsch, Dr. H. A. Pilsbry, Dr. Julia Gardner, and Dr. W. C. Mansfield. Workers at the United States National Museum will sorely miss Doctor Dall, who was ever willing to be interrupted, no matter how pressing the work on which he was engaged, and to give freely from his great store of information. I frequently consulted with Dr. Ralph Stewart, of Johns Hopkins University and the University of California, whose "Revision of Gabb's California Type Gastropods" marks an important step in the study of American Cretaceous and Tertiary mollusks. Prof. G. D. Harris, of Cornell University, offered the facilities of his laboratory during a visit to examine types. Dr. T. Wayland Vaughan, under whose general direction the project was completed, reviewed the discussion of results,

so that I have had the benefit of his extensive knowledge of the geology and palaeontology of the West Indian and other regions. I am deeply indebted to Dr. J. C. Merriam, President of the Carnegie Institution of Washington, through whose interest and assistance the project was completed. Dr. M. I. Goldman, of the United States Geological Survey, made many suggestions as to the interpretation of the ecology of the Bowden mollusks. I also wish to thank the Director and Chief Geologist of the United States Geological Survey for the opportunity to complete the report. Mr. L. R. Cox, of the Department of Geology of the British Museum, generously responded to appeals for the loan of type material and assisted in other ways. Finally, I wish to express my great obligations to Prof. E. W. Berry, of Johns Hopkins University, under whose direction this account of the Bowden mollusks was planned and whose inspiring example prompted the attempt to do something more than describe species.

NEW GENERA, SUBGENERA, AND SECTIONS, WITH THEIR TYPE SPECIES

Acmaturris. Type: *A. comparata*, new species.

Adelocythara. Type: *A. primolevis*, new species.

Agladrillia. Type: *A. callothyra*, new species.

Antillachelus. Type: *Calliostoma (Dentistyla) asperrium* var. *dentiferum* Dall.

Antillophos (subgenus of *Tritiaria*). Type: *Cancellaria candei* d'Orbigny.

Bactrocythara. Type: *Cythara obtusa* Guppy.

Bowdenagaza (subgenus of *Microgaza*). Type: *Microgaza (Bowdenagaza) cossmanni*, new species.

Brachycythara. Type: *Cythara gibba* Guppy.

Cibdezebina (subgenus of *Rissoina*). Type: *Rissoina browniana* d'Orbigny.

Cigclirina. Type: *C. sigma*, new species.

Coanollonia. Type: *C. ambla*, new species.

Compsodrillia. Type: *C. urceola*, new species.

Cryoturris. Type: *C. engonia*, new species.

Dactylidella (section of *Olivella*). Type: *Oliva anazora* Duclos.

Didianema. Type: *D. tytha*, new species.

Engoniophos. Type: *Phos erectus* Guppy.

Euctathurella. Type: *Clathurella vendryesiana* Dall.

Eumetadrillia (subgenus of *Agladrillia*). Type: *Agladrillia (Eumetadrillia) serra*, new species.

Eurissolina (subgenus of *Rissoina*). Type: *Rissoina (Eurissolina) ditomus*, new species.

- Euryentmema*. Type: *E. cigclis*, new species.
Eurypyrene (subgenus of *Pyrene*). Type: *Pyrene* (*Eurypyrene*) *eurynotum*, new species.
Fusiturricula. Type: *Turris* (*Surcula*) *fusinella* Dall.
Globidrillia. Type: *C. ula*, new species.
Glyphoturris. Type: *Mangilia quadrata* var. *rugirima* Dall.
Ithythythara. Type: *Mangilia psila* Bush.
Leptadrillia. Type: *Turris* (*Surcula*) *parkeri* Gabb.
Leptegouana (section of *Marginella*). Type: *Voluta guttata* Dillwyn.
Leptothyropsis (subgenus of *Homalapoma*). Type: *Leptothyra philipiana* Dall.
Lioglyphostoma. Type: *L. adematum*, new species.
Mirachelus. Type: *Calliostoma corbis* Dall.
Miraclothurella. Type: *M. vittata*, new species.
Mirarissoina (subgenus of *Rissoina*). Type: *Rissoina* (*Mirarissoina*) *lepida*, new species.
Ochetoclava (subgenus of *Clava*). Type: *Cerithium gemmatum* Hinds.
Otollonia. Type: *Liotia siderea* Guppy.
Pachycrommium. Type: *Amaura guppyi* Gabb.
Pachythythara. Type: *P. cryptonata*, new species.
Paraterebra (subgenus of *Terebra*). Type: *Terebra texana* Dall.
Platythythara. Type: *P. eurystoma*, new species.
Polystira. Type: *Pleurotoma albida* Perry.
Psilaxis (section of *Architectonica*). Type: *Architectonica* (*Philippia*) *krebsii* Mörch.
Pyrgocythara. Type: *P. eminula*, new species.
Saccharoturris. Type: *Mangilia consentanea* Guppy.
Syntomodrillia. Type: *Drillia lissotropis* Dall.
Taeniaturbo (section of *Turbo*). Type: *Turbo canaliculatus* Herrmann.
Tenaturris. Type: *Cythara guppyi* Dall.
Thelecythara. Type: *Cythara mucronata* Guppy.
Trachypollia. Type: *T. sclera*, new species.
Tylocassis (subgenus of *Semicassis*). Type: *Buccinum inflatum* Shaw.
Vaughanites. Type: *V. leptus*, new species.

COMPOSITION OF THE BOWDEN FAUNA

GENERAL FEATURES

The following mollusks from the Bowden formation are considered in this report and in Publication 366. Other Bowden fossils that have been described are included, so as to make available for ready reference a full faunal list. Changes in the names used for the pelecypods, other than a change in rank, are discussed in footnotes.

Mollusks and other fossils from Bowden formation

Foraminifera (described by J. A. Cushman, Carnegie Inst. Washington Pub. 291, pp. 21-71, 15 pls., 8 figs., 1919):

Psammosphaera fusca Schulze
Haplostiche dubia intermedia (Vanden Broeck)
Haddonina minor Chapman
Textularia barretti Jones and Parker
Cuneolina pavonia d'Orbigny
Cuneolina pavonia angusta Cushman
Bulimina ovata d'Orbigny
Nodosaria vertebralis (Batsch)
Fronicularia alata d'Orbigny
Cristellaria calcar aspinosa Cushman
Cristellaria bowdenensis Cushman
Cristellaria italica (de France)
Cristellaria gemmata H. B. Brady
Globigerina bulloides d'Orbigny
Globigerina rubra d'Orbigny
Globigerina sacculifera H. B. Brady
Globigerina subcretacea Chapman
Sphaeroidina dehiscens immatura Cushman
Discorbis allomorphinoides (Reuss)
Truncatulina praecincta (Karrer)
Gypsina vesicularis (Parker and Jones)
Gypsina globulus pilaris (H. B. Brady)
Pulvinulina sagra (d'Orbigny)
Amphistegina lessonii d'Orbigny
Quinqueloculina auberiana d'Orbigny
Quinqueloculina parkeri bowdenensis Cushman
Triloculina brongniartiana d'Orbigny
Triloculina tricarinata d'Orbigny
Vertebralina striata d'Orbigny
Orbiculina compressa d'Orbigny

Corals (listed and described in part by T. W. Vaughan, U. S. Nat. Mus. Bull. 103, pp. 212-213, 340-341, 355-360, 443-447, 499-500, 1919):

Placotrochus costatus Duncan
Sphenotrochus, new species
Placocyathus barretti Duncan
Placocyathus alveolus (Duncan)

Stylophora granulata Duncan
Asterosmilia profunda (Duncan)
Asterosmilia hilli Vaughan
Stephanocoenia intersepta (Esper)
Antillia walli Duncan
Thysanus excentricus Duncan
Thysanus elegans Duncan
Thysanus, new species
Syzygophyllia gregorii (Vaughan)
Siderastrea siderea (Ellis and Solander)
Goniopora, new species
Porites baracoënsis Vaughan
Acropora, new species

Bryozoa (described by F. Canu and R. S. Bassler, Carnegie Inst. Washington
 Pub. 291, pp. 73-102, 7 pls., 1919; U. S. Nat. Mus. Bull. 125, 301 pp.,
 47 pls., 38 figs., 1923 (see pp. 5 to 6):

Terebripora elongata Canu and Bassler
Terebripora sinefilum Canu and Bassler
Membranipora osburni Canu and Bassler
Membranipora tenella Hincks
Conopeum lacroixii Busk
Conopeum ovale Canu and Bassler
Cupuladria canariensis Busk
Acanthodesia savartii textura Reuss
Membrendoecium parvicapitatum Canu and Bassler
Callopora dumerillii Savigny-Audouin
Hemiseptella grandicella Canu and Bassler
Cupularia umbellata de France
Thalamoporella biperforata Canu and Bassler
Steganoporella parvicella Canu and Bassler
Stephanosella biaptera Michelin
Schizopodrella unicornis Johnston
Stylopoma spongites Pallas (not recorded in 1923 report)
Stylopoma minuta Canu and Bassler
Gemelliporella punctata Canu and Bassler
Hippodiplosia baccata Canu and Bassler
Cycloperiella rubra Canu and Bassler
Aimulosia brevis Canu and Bassler
Smittina ophidiana Waters
Rhamphostomella laticella Canu and Bassler
Rhamphostomella granulosa Canu and Bassler
Rhynchozoon verruculatum Smitt
Adeona heckeli Reuss
Bracebridgia deformis Canu and Bassler
Metrarabdotos lacrymosum Canu and Bassler
Mastigophora granulosa Canu and Bassler
Holoporella albirostris Smitt
Holoporella hemispherica Canu and Bassler
Mamillopora tuberosa Canu and Bassler

Mollusks:

Gastropods:

- Tralia* (*Tralia*) *vetula* Woodring
- Siphonaria* species
- Williamia* *parva* Woodring
- Cavolina* *telemus* (Linné)
- Cavolina* *ventricosa* (Guppy)
- Cavolina* *digitata* (Guppy)
- Cavolina* *vendryesiana* (Guppy)
- Diacria* *bisulcata* Gabb
- Acteon* *textilis* (Guppy)
- Acteon* *eurystoma* Woodring
- Acteon* *riomaensis* Maury
- Acteocina* *subbullata* Pilsbry and Johnson
- Acteocina* *lepta* Woodring
- Acteocina* *anetaspira* Woodring
- Acteocina* *coixlacryma* (Guppy)
- Sulcularia* *lipara* Woodring
- Cylichnella* *atacata* Woodring
- Volvula* *oxytata* Bush
- Volvula* *ornata* Pilsbry and Johnson
- Scaphander* *nannus* Woodring
- Atys* (*Aliculastrum*) *morantensis* Woodring
- Atys* (*Aliculastrum*) *dalli* Woodring
- Cylichna* *aula* Woodring
- Bulla* *vendryesiana* Guppy
- Ringicula* (*Ringiculella*) *tridentata* Guppy
- Atlanta* (*Atlanta*) *diamesa* Woodring
- Atlanta* (*Atlantidea*) *lissa* Woodring
- Terebra* (*Paraterebra*) *lepta* Woodring
- Terebra* (*Paraterebra*) species
- Terebra* (*Strioterebrum*) *bowdenensis* Woodring
- Terebra* (*Strioterebrum*) *eleutheria* Woodring
- Terebra* (*Strioterebrum*) species *a*
- Terebra* (*Strioterebrum*) species *b*
- Terebra* (*Strioterebrum*) species *c*
- Terebra* (*Strioterebrum*) *monida* Woodring
- Terebra* (*Strioterebrum*) *ischna* Woodring
- Terebra* (*Strioterebrum*) *cambiarsoi nugatoria* Woodring
- Hastula* *jamaicensis* Woodring
- Hastula* *homala* Woodring
- Polystira* *barretti* (Guppy)
- Crassispira* *jamaicensis* (Guppy)
- Crassispira* *ponida* Woodring
- Crassispira* *lomata* Woodring
- Crassispira* *annella* Woodring
- Crassispira* *aegis* Woodring
- Clathrodrillia* *tityra* Woodring
- Carinodrillia* *elocata meta* Woodring

Carinodrillia bocatoroensis (Olsson)
Compsodrillia urceola Woodring
Compsodrillia catherina Woodring
Compsodrillia senaria Woodring
Agladrillia (Agladrillia) callothyra Woodring
Agladrillia (Agladrillia) leptalea Woodring
Agladrillia (Eumetadrillia) serra Woodring
Leptadrillia parkeri (Gabb)
Syntomodrillia espyra Woodring
Syntomodrillia iphis Woodring
"Drillia" species
Bellaspira ? species
Globidrillia ula Woodring
Ancistrotyrinx miranda (Guppy)
Fusiturricula iole Woodring
Fusiturricula panola Woodring
Ithyocythara psiloides Woodring
Ithyocythara ischna Woodring
Ithyocythara maera Woodring
Ithyocythara species
Ithyocythara scissa Woodring
Adelocythara primolevis Woodring
Pyrgocythara eminula Woodring
Platyocythara eurytoma Woodring
Theleocythara mucronata (Guppy)
Bactrocythara obtusa (Guppy)
Pachyocythara cryptonata Woodring
Brachyocythara gibba (Guppy)
Brachyocythara species
"Cythara" species
Glyphoturris lampra Woodring
Cryoturris engonia Woodring
Cryoturris euengonia Woodring
Cryoturris nexilis Woodring
Cryoturris nisis Woodring
Cryoturris etrema Woodring
Cryoturris dianema Woodring
Cryoturris aptera Woodring
Saccharoturris consentanea (Guppy)
Saccharoturris species
Acmaturris comparata Woodring
Acmaturris brisis Woodring
Acmaturris scalida Woodring
Tenaturris guppyi (Dall)
Tenaturris terpna Woodring
Tenaturris isiola Woodring
Euclathurella vendryesiana (Dall)
Miraclathurella vittata Woodring
Miraclathurella entemna Woodring

Miraclathurella species
 Glyphostoma exopitatum Woodring
 Glyphostoma guppyi Woodring
 Lioglyphostoma adematum Woodring
 Lioglyphostoma moinica (Olsson)
 Nannodiella amicta (Guppy)
 Euryentmema cigclis Woodring
 Euryentmema species
 Microdrillia tersa Woodring
 Daphnella ? species
 "Daphnella" species
 Scobinella magnifica (Gabb)
 Vaughanites leptus Woodring
 Conus (Dendroconus) apium Woodring
 Conus (Lithoconus) species
 Conus (Lithoconus) proteus Hwass
 Conus (Lithoconus) ancylus Woodring
 Conus (Lithoconus) nannus Woodring
 Conus (Lithoconus) guppyi Woodring
 Conus (Chelyconus) oniscus Woodring
 Conus (Leptoconus) stenostoma Sowerby
 Conus (Leptoconus) imitator lius Woodring
 Conus (Leptoconus) planiliratus Sowerby
 Conus (Leptoconus) multiliratus gaza Johnson and Pilsbry
 Conus (Leptoconus) catenatus Sowerby
 Conus (Leptoconus) consobrinus Sowerby
 Conus (Leptoconus) granozonatus Guppy
 Conus (Leptoconus) gracilissimus Guppy
 Conus (Leptoconus) stibarus Woodring
 Cancellaria (Cancellaria) barretti Guppy
 Cancellaria (Cancellaria) laeescens Guppy
 Cancellaria (Bivetopsis) moorei Guppy
 Tribia epomis Woodring
 Trigonostoma scalatella Guppy
 "Cancellaria" species
 Oliva (Oliva) reticularis trochala Woodring
 Oliva (Oliva) plicata Guppy
 Olivella (Olivella) acra Woodring
 Olivella (Olivella) elarki Woodring
 Olivella (Callianax) unica Woodring
 Olivella (Dactylidia) indivisa Guppy
 Olivella (Dactylidella) colpus Woodring
 Ancilla (Eburna) pinguis Guppy
 Marginella (Volvarina) species
 Marginella (Leptegouana) coniformis Sowerby
 Marginella (Serrata) glaphyra Woodring
 Marginella (Serrata) mauryae Woodring
 Cypraeolina pyena Woodring
 Mitra (Tiara) henekeni illacidata Woodring

Mitra (Tiara) rhadina Woodring
 Vexillum (Costellaria) dasaplurum Woodring
 Vexillum (Costellaria) micramadum Woodring
 Vexillum (Costellaria) cryptidulum Woodring
 Vexillum (Costellaria) leurum Woodring
 Vexillum (Uromitra) syntomum Woodring
 Vexillum (Uromitra) callipictum Woodring
 Vexillum (Uromitra) voraginosum Woodring
 Vexillum (Uromitra) uncidum Woodring
 Mitromorpha species
 Xancus textilis (Guppy)
 Xancus species
 Latirus (Polygona) infundibulum polius Woodring
 Latirus (Polygona) nematus Woodring
 Fasciolaria semistriata leura Woodring
 Fusinus species
 Fusinus engonius Woodring
 Tritiaria (Antillophos) moorei (Guppy)
 Tritiaria (Antillophos) elegans (Guppy)
 Engoniophos erectus (Guppy)
 Nassarius (Uzita) cercadensis (Maury)
 Nassarius (Uzita) gurabensis (Maury)
 Trachypollia sclera Woodring
 Columbella submercatoria Olsson
 Columbella platynema Woodring
 Pyrene (Eurypyrene) eurynotum Woodring
 Mitrella (Mitrella) ocellata bowdenensis Woodring
 Mitrella (Columbellopsis) lissa Woodring
 Mitrella (Columbellopsis) lepta Woodring
 Mitrella (Columbellopsis) species
 Anachis (Costoanachis) orthopleura Woodring
 Anachis (Costoanachis) aulata Woodring
 Metuella (Metuella) species
 Nassarina orna Woodring
 Nassarina species
 Cigclirina sigma Woodring
 Strombina guppyi Woodring
 Strombina gradata (Guppy)
 Strombina caribaea Gabb
 "Strombina" species
 Metula species
 Murex (Murex) recurvirostris Broderip
 Murex (Phyllonotus) pomum Gmelin
 "Muricopsis" collatus (Guppy)
 "Muricopsis" species
 Typhis (Typhinellus) siphon Woodring
 Typhis (Talityphus) alatus obesus Gabb
 Thais (Stramonita ?) species
 Coralliophila miocenica (Guppy)

Cymatium (Lampusia) species *a*
 Cymatium (Lampusia) species *b*
 Cymatium (Guttarium) species
 Distorsio (Distorsio) decussatus similimus (Sowerby)
 Distorsio (Distorsio) clathratus gatunensis Toulà
 Bursa (Marsupina) proavus bowdenensis Pilsbry
 Cassis sulcifera Sowerby
 Semicassis (Tylocassis) reclusa (Guppy)
 Sconsia (Sconsia) striata sublaevigata (Guppy)
 Malea camura Guppy
 Ficus pilsbryi (B. Smith)
 Simnia (Calpurnia) immunita (Guppy)
 Cypraea (Talparia) isabella patrespatriae Maury
 Cypraea (Zonaria) raymondrobertsi bowdenensis Pilsbry
 Trivia (Trivia) cypha Woodring
 Trivia (Trivia) globosa ("Gray") Sowerby
 Trivia (Trivia) pediculus (Linné)
 Erato (Erato) domingensis trochala Woodring
 Strombus pugiloides Guppy
 Strombus bifrons Sowerby
 Strombus species
 Strombus leurus Woodring
 Seguenzia hapala Woodring
 Triphora tritreta Woodring
 Triphora apania Woodring
 Triphora species *a*
 Triphora species *b*
 Cerithiopsis compsa Woodring
 Cerithiopsis cigelis Woodring
 Dizoniopsis vaughani Woodring
 "Cerithiella" species
 Seila species
 Thericium species *a*
 Thericium species *b*
 Clava (Ochetoclava) costaricana stena Woodring
 Clava (Ochetoclava) terpna Woodring
 Bittium praeformatum Guppy
 Bittium species
 Bittium properatum Woodring
 Alabina curta Woodring
 Alaba turrita Guppy
 Planaxis ame Woodring
 Modulus modulus basileus Guppy
 Vermicularia spirata (Philippi)
 Lemintina papulosa (Guppy)
 Petaloconchus species
 Turritella guppyi Cossmann
 Caecum species
 Meioceras apanium Woodring

"Fossarus" species
 "Fossarus (Gottoina)" mundulus Guppy
 "Fossarus (Gottoina)" comptus Woodring
 Architectonica (Architectonica) nobilis quadriseriata (Sowerby)
 Architectonica (Psilaxis) krebsii lampra Woodring
 Architectonica (Psilaxis) araea Woodring
 Architectonica (Pseudotorinia) euprepes Woodring
 Architectonica (Nipteraxis) species
 Spirolaxis exquisita (Dall and Simpson)
 Crepitacella cepula (Guppy)
 Crepitacella aresca Woodring
 Rissoina species
 Rissoina (Zebinella) ame Woodring
 Rissoina (Zebinella) oligopleura Woodring
 Rissoina (Zebinella) species
 Rissoina (Mirarissolina) lepida Woodring
 Rissoina (Mirarissolina) species
 Rissoina (Mirarissolina) xesta Woodring
 Rissoina (Phosinella) guppyi Cossmann
 Rissoina (Phosinella) rituola Woodring
 Rissoina (Phosinella) pyrgus Woodring
 Rissoina (Phosinella) species
 Rissoina (Phosinella) debussa Woodring
 Rissoina (Eurissolina) ditomus Woodring
 Rissoina (Cibdezebina) browniana d'Orbigny
 Rissoidae—3 species
 Capulus (Capulus) epicranum Woodring
 Capulus (Malluvium) lius Woodring
 Hipponix ceras Woodring
 "Hipponix" tortilis Guppy
 Cheilea "equestris (Linné)"
 Xenophora delecta (Guppy)
 Natica (Natica) castrenoides Woodring
 Natica (Natica) species
 Natica (Naticarius) canrena antinacca Cossmann
 Natica (Naticarius) species
 Stigmaulax vererugosum Cossmann
 Tectonatica pusilla (Say)
 Polinices brunnea subclausa (Sowerby)
 Eunaticina regia (Guppy)
 Sigatica semisulcata bathyora Woodring
 Sinum gatunense (Toula)
 Sinum species
 Sinum excentricum (Guppy)
 Pachycrommium guppyi (Gabb)
 Epitonium (Cycloscala) vetulum Woodring
 Epitonium (Cycloscala) eumetrum Woodring
 Epitonium (Hirtoscala) species
 Epitonium (Spiniscala) gabbi (de Boury)

Epitonium (Spiniscala) etolium Woodring
 Epitonium (Spiniscala ?) alidotum Woodring
 Epitonium (Striatascala) anlanum Woodring
 Epitonium (Striatascala) callipictum Woodring
 Epitonium (Nitidiscala) aduncum Woodring
 Epitonium (Nitidiscala) ventulum Woodring
 Epitonium (Pictoscala) lepta Woodring
 Ferminoscala pseudoleroyi (Maury)
 Ferminoscala spathe Woodring
 "Pliciscala (Nodiscala)" dasystoma Woodring
 Janthina species
 Mathilda plexita Dall
 Mathilda species
 Pyramidellidae—35 species
 Melanellidae—12 species
 Turbo (Taeniaturbo) dominicensis Gabb
 Turbo (Taeniaturbo) species
 Turbo (Senectus) species
 Astraea (Astrarium) sublongispina acosmeta Woodring
 Astraea (Astrarium) brevispina basilis Olsson
 Astraea (Lithopoma) species
 Homalopoma (Leptothyropsis) philipiana oedamata Woodring
 Otollonia siderea (Guppy)
 Coanollonia ambla Woodring
 Coanollonia ? species
 Tricolia (Tricolia) umbilicata (d'Orbigny)
 Tricolia (Eulithidium) hadra Woodring
 Liotia (Liotia) strebla Woodring
 Liotia (Arene) lepidota Woodring
 Liotia (Arene) venusta Woodring
 Neritina (Nereina) woodwardi Guppy
 Neritina (Clypeolum) pterota Woodring
 Smaragdia (Smaragdia) viridis viridemaris (Maury)
 Calliostoma (Calliostoma) pulcher bowdenense Woodring
 Calliostoma (Calliostoma) roseoloide Woodring
 Calliostoma (Dentistyla) guppyi Woodring
 Solariella altiusulca Guppy
 Solariella veresimilis (Guppy)
 Antillachelus vughani Woodring
 Mirachelus precorbis Woodring
 Microgaza (Microgaza) rotella vetula Woodring
 Microgaza (Bowdenagaza) cossmanni Woodring
 Chlorostoma (Omphalius) species
 Vitrinella gabbi Woodring
 "Circulus" bicarinatus (Guppy)
 "Circulus" partulus Woodring
 "Circulus" pentagonus (Gabb)
 Episcynia naso (Pilsbry and Johnson)
 Solariorbis clypeatus Guppy

Solariorbis colpus Woodring
Teinostoma (*Teinostoma*) *laccus* Woodring
Pseudorotella pycna Woodring
Pseudorotella homala Woodring
Didianema tytha Woodring
Cocculina decussata Woodring
Cocculina pustulata Woodring
Fissurella (*Fissurella*) *arguta* Woodring
Lucapina lipara Woodring
Lucapinella limatula vetula Woodring
Diodora alternata henekeni (Maury)
Diodora compsa Woodring
Puncturella (*Fissurisepta*) *vetula* Woodring
Emarginula (*Emarginula*) *palia* Woodring
Rimula pilsbryi Woodring
Hemitoma (*Hemitoma*) *sclera* Woodring
Acmaea actina Woodring
Acmaea acra Woodring

Scaphopods:

Dentalium (*Dentalium*) *cossmannianum* Pilsbry and Sharp
Dentalium (*Dentalium*) *glaucoterrarum* Maury
Dentalium (*Dentalium* ?) *species a*
Dentalium (*Dentalium* ?) *species b*
Dentalium (*Tesseracme*) *dissimile dissimile* Guppy
Dentalium (*Tesseracme*) *dissimile ponderosum* Gabb
Dentalium (*Graptacme*) *species a*
Dentalium (*Graptacme*) *species b*
Dentalium (*Laevidentalium*) *haytense* Gabb
Dentalium (*Episiphon*) *schumoi* Pilsbry
Dentalium (*Episiphon*) *macilentum* Pilsbry
Cadulus (*Cadulus*) *simrothi* Pilsbry
Cadulus (*Gadilopsis*) *dentalinus* (Guppy)
Cadulus (*Gadilopsis*) *hendersoni* Woodring
Cadulus (*Polyschides*) *annulatus* Pilsbry
Cadulus (*Platyschides*) *depressicolis* Pilsbry and Sharp
Cadulus (*Platyschides*) *pilsbryi* Woodring
Cadulus (*Platyschides*) *species*
Cadulus (*Platyschides*) *annectens* Woodring
Cadulus (*Platyschides*) *arrosus* Woodring

Pelecypods:

Nucula (*Nucula*) *morantensis* Woodring
Nucula ("Nuculopsis")¹ *hilli* Woodring
*Nuculana*² (*Sacella*) *peltella* (Dall)
Nuculana (*Sacella*) *subcerata* (Woodring)

¹ *Nuculopsis* is twice preoccupied (Girty, Ann. New York Acad. Sci., vol. 21, p. 133, 1911. Rollier, Abh. Schweizerischen Pal. Ges., vol. 38, p. 64, 1912).

² *Nuculana* Link (Besch. Natur.-Samml. Univ. Rostock, p. 155, 1806; type, by monotypy), *Nuculana rostrata* (Gmelin) (*Arca rostrata* Gmelin) takes precedence over *Leda* Schumacher, 1817.

Nuculana (*Saccella*) *indigena* (Dall)
Nuculana (*Jupiteria*) *bowdenensis bowdenensis* (Woodring)
Nuculana (*Jupiteria*) *bowdenensis subtumida* (Woodring)
Nuculana (*Jupiteria*) *duerdeni* (Woodring)
Nuculana (*Pseudoportlandia*) *clara* (Guppy)
Yoldia (*Orthoyoldia*) *ovalis* Gabb
Tindaria (*Tindaria*) *species*
Glycymeris (*Glycymeris*) *jamaicensis* Dall
Glycymeris (*Glycymeris*) *acuticostata plasias* Woodring
Glycymeris (*Glycymerella*) *prepennacea* Woodring
*"Arca"*¹ *occidentalis* Philippi
"Arca" *umbonata morantensis* Woodring
"Arca" *bowdeniana* Dall
"Arca" *yaquensis berryi* Woodring
Barbatia (*Barbatia*) *islopa* Woodring²
Barbatia (*Barbatia*) *delepida* Woodring
Barbatia (*Barbatia*) *inuitata* Woodring³
Barbatia (*Acar*) *domingensis* (Lamarck)
Barbatia (*Obliquarca*) *dentera* Woodring
Barbatia (*Obliquarca*) *subcandida* Woodring
Barbatia (*Obliquarca*) *modiolida* Woodring
*Anadara*⁴ *halidonata halidonata* (Dall)
Anadara *halidonata oresta* (Woodring)
Anadara *perplura* (Woodring)
Anadara *prephina* (Woodring)
Anadara *inaequilateralis* (Guppy)
Anadara *dasia* (Woodring)
Anadara *wordeni* (Woodring)
Anadara *agnastha* (Woodring)
Anadara *actinophora thomasensis* (Woodring)
Anadara *donacia* (Dall)
Anadara *microtera* (Woodring)
Anadara *opthanta* (Woodring)
Fossularca *adamsi* (Dall)⁵
Ovalarca *ovalina* (Dall)
Bathyarca *hendersoni* (Dall)
Limopsis (*Pectunculina*) *ovalis silova* Woodring
Limopsis (*Pectunculina*) *jamaicensis* Woodring
Pinna *refurca* Woodring
Atrina *species*

¹ According to the designation of *A. tortuosa* Linné as the type of *Arca* by Children in "1823," that well-known name is not available for this genus (see Cox, Pal. Zanzibar Protectorate, p. 93, 1927). This is one of the unfortunate results of subsequent designation.

² *B. endomena* Woodring seems to be a synonym of this species.

³ *B. propretua* Woodring is suppressed as a synonym of this species.

⁴ L. R. Cox, of the Department of Geology of the British Museum, after examining the type of *Arca antiquata* Linné informs me that it has no byssal gape and that some specimens of this species have ligament grooves and others have none. *Diluvarca* is suppressed as a synonym of *Anadara* (see Cox, Pal. Zanzibar Protectorate, pp. 94-95, 1927).

⁵ The subspecific name *sawkinsi* apparently should be suppressed.

*Pedalion*¹ species
Pteria inornata (Gabb)
Ostrea (Lopha) *paramegodon* Woodring
Ostrea (Lopha) *costaricensis* Olsson²
Ostrea (Lopha) *folioides* Woodring
Pecten (Euvola) *barretti* Woodring³
Pecten (Euvola) *bowdenensis* Dall
Chlamys (Chlamys) species
Chlamys (Chlamys) *vaginulus* (Dall)
Chlamys ("Chlamys") *bellipictus* Woodring
Chlamys (Aequipecten) *plurinominis morantensis* Woodring
Chlamys (Plagiectenium) *uselmæ* (Pilsbry and Johnson)⁴
Chlamys (Plagiectenium) *concinnatus* Woodring
Chlamys (Plagiectenium) *ameleus* Woodring
Chlamys (Plagiectenium) *gonioides* Woodring
Chlamys (Nodipecten) *nodosus* (Linné)⁵
"Palliolum" ? *guppyi* (Dall)⁶
Amusium (Amusium) *papyraceum* (Gabb) ?
Amusium (Parvamussium) *spendulum* Woodring
Spondylus bostrychites Guppy
Spondylus species
Plicatula guppyi Woodring
Lima (Lima) *stenacostata* Woodring
Lima (Mantellum) species
Limea solida Dall
Placunanomia lithobleta Dall
Anomia indecisa Dall
Modiolus (Brachydontes) *guppyi* Dall
Mytilopsis jamaicensis Woodring
Julia gardnerae Woodring
Poromya jamaicensis Dall
Cuspidaria (Cardiomya) *craspedonia* Dall
Cuspidaria (Bowdenia) *distira* Dall
Verticordia (Trigonulina) *bowdenensis* Dall
Verticordia (Haliris) *jamaicensis* Dall
*"Crassatellites"*⁷ *jamaicensis* Dall
"Crassatellites" *altaspissus* Woodring
Crassinella guppyi (Dall)
Crassinella bowdenensis (Dall)
Crassinella xena Woodring
Cardita (Glans) *scabricostata* Guppy

¹ According to Iredale (Proc. Linn. Soc. New South Wales, vol. 49, p. 190, 1924), *Pedalion* Huddesford (Huddesford's ed. of Lister, index, p. 23, 1770) probably is the earliest name for this genus.

² *O. guppyi* Woodring is considered a synonym of this species.

³ This species seems to fall in *Euvola* rather than in *Pecten* s. s.

⁴ *Chlamys mansfieldi* Woodring is suppressed as a synonym of this species.

⁵ This species is represented in material donated to the United States National Museum by T. H. Aldrich.

⁶ The group of *Pecten*s to which this species belongs seems to be unnamed.

⁷ This generic name is not available for the Bowden species.

Pleuromeris acaris (Dall)
Chama involuta Guppy
Chama macerophylla Gmelin
Echinochama antiquata Dall
Codakia (*Codakia*) *spinulosa* Dall
Codakia (*Codakia*) *lomonea* Woodring
Codakia (*Jagonia*) *vendryesi* Dall
Codakia (*Jagonia*) *guppyi* Woodring
Lucina (*Lucina*) *bowdenensis* Woodring¹
Myrtaea (*Miyrtaea*) *limoniana* Dall
Myrtaea (*Myrteopsis*) *pertenera* (Dall)
Myrtaea (*Eulopia*) *vermiculata* Dall
Myrtaea (*Eulopia*) *furcata* Dall
Miltha (*Megaxinus*) *gluminda* Woodring
*Phacoides*² (*Phacoides* ?) species
Phacoides (*Linga*) *podagrinus podagrinus* Dall
Phacoides (*Linga*) *podagrinus alarantus* Woodring
Phacoides (*Linga*) *browni* Woodring
Phacoides (*Linga*) *tithonis* Dall
Phacoides (*Pleurolucina*) *quadricostatus* Dall
Phacoides (*Cardiolucina*) *recurrens* Dall
Phacoides (*Callucina*) *pauperatus pauperatus* (Guppy)
Phacoides (*Callucina*) *pauperatus oligocostatus* Woodring
Phacoides (*Callucina*) *eurycostatus* Woodring
Phacoides (*Parvilucina*) *yaquensis morantensis* Woodring
Phacoides (*Parvilucina*) *limnidus* Woodring
Phacoides (*Bellucina*) *actinus* Dall
Divaricella (*Divaricella*) *prevaricata* Guppy
Diplodonta (*Diplodonta*) *walli* Woodring
Diplodonta (*Diplodonta*) *homalostriata* Woodring
Diplodonta (*Felaniella*) *minor* Dall
Diplodonta (*Phlyctiderma*) *gabbi* Dall
Erycina (*Erycina*) *olssoni* Woodring
Erycina (*Erycina*) *pura* Woodring
Neaeromya *menotreta* Woodring
Cardium ("Acanthocardia ?") *dissidepictum* Woodring
Cardium (*Trachycardium*) *lingualeonis* Guppy
Cardium (*Trachycardium*) *bowdenense* Dall
Cardium (*Trachycardium*) *inconspicuum* Guppy
Cardium (*Trachycardium*) *waylandi* Woodring
Cardium (*Fragum*) *medium* Linné
Cardium (*Fragum*) *elattocostatum* Woodring

¹ Material that was found after Publication 366 was issued shows that this species gets to be more than twice as large as the type.

² Iredale's (Proc. Malac. Soc. London, vol. 11, pp. 301-302, 1915) contention that *Phacoides* as used by Blainville is a vernacular name seems to be fully justified, but his refusal to accept it as of Gray, 1847, is open to question, for it is available as a substitute name for *Lucina* Gray, not Bruguière (see Iredale's discussion of *Lucina*). According to the view here taken the citation for *Phacoides* should be as follows: Gray, 1847, Proc. Zool. Soc. London, pt. 15, p. 195, type, by original designation, "*Venus*" *jamaicensis* [Spengler], apparently error for *Tellina*.

Cardium (Trigoniocardia) haitense haitense Sowerby
 Cardium (Trigoniocardia) haitense cercadicum Maury
 Cardium (Trigoniocardia) thaumastum Woodring
 Cardium (Laevicardium) serratum Linné
 "Nemocardium"¹ jamaicense (Dall)
 Pliocardia bowdeniana (Dall)
 Tivela (Tivela) jamaicensis Dall
 Gouldia insularis (Dall and Simpson)
 Pitar (Pitarella) gatunensis (Dall)²
 Pitar (Hyphantosoma) carbaseus (Guppy)
 "Callista" (Costacallista) planivieta (Guppy)³
 Antigua (Dosina) caesarina (Dall)⁴
 Antigua (Ventricola) blandiana (Guppy)
 Cyclinella plasiatenuis Woodring
 Chione (Chione) sawkinsi Woodring
 Chione (Chione) woodwardi (Guppy)
 Chione (Chione) retugida Woodring⁵
 Chione (Lirophora) hendersonii Dall
 Chione (Timoclea) granulata (Gmelin)⁶
 Parastarte antillensis Woodring
 Cooperella (Cooperellopsis) thaumasta Woodring
 Tellina (Moerella) simpsoni Dall
 Tellina (Moerella) hendersoni Dall
 Tellina (Eurytellina) species
 Tellina (Eurytellina) spiekeri Woodring
 Tellina (Eurytellina) pharcida Dall
 Tellina (Eurytellina) gonida Woodring
 Tellina (Eurytellina) halistrepta Dall
 Tellina (Eurytellina) apomsa Woodring
 Tellina (Eurytellina) browni Woodring
 Tellina (Merisca) species
 Tellina (Merisca) sclera sclera Dall
 Tellina (Merisca) sclera lerasca Woodring
 Tellina (Merisca) acrocsmia Dall
 Tellina (Scissula) healeyi Woodring
 Tellina (Elliptotellina) cymobia Woodring
 Strigilla (Strigilla) pisiformis (Linné)
 Macoma (Psammacoma) tracta Dall
 Macoma (Psammacoma) olivella Dall
 Macoma (Cymatoica) vendryesi Dall
 Semele (Semele) calliconcinnata Woodring
 Abra (Abra) triangulata Dall

¹ This species is not like the type of *Nemocardium*.

² Material submitted by Mr. Aldrich indicates that "*Callocardia*" *ammondea* Woodring and "*C. eleuthusa* Woodring should be suppressed as synonyms of this species.

³ See Palmer, *Palaeontographica Americana*, vol. 1, No. 5, p. 89, 1927.

⁴ Recorded by Palmer, *Palaeontographica Americana*, vol. 1, No. 5, p. 126, 1927.

⁵ Palmer's record of *C. subrostrata* (Lamarck) (*Palaeontographica Americana*, vol. 1, No. 5, p. 150, 1927) may refer to this species, which she incorrectly places in *Timoclea*, but I have not seen specimens.

⁶ Recorded by Palmer, *Palaeontographica Americana*, vol. 1, No. 5, pp. 158-159, 1927.

Abra (Abra) deuthera Woodring
 Donax (Donax) species
 Donax (Paradonax) lennoxii Woodring
 Solecuretus¹ sanetidominici (Maury)
 Spisula (Mactromeris) matleyi Woodring
 Ervilia gabbi Woodring
 Corbula (Corbula)² heterogena Dall
 Corbula (Caryocorbula)² sericea Dall
 Corbula (Bothrocorbula) viminea Guppy
 Basterotia (Basterotia) bowdeniana (Dall)
 Rocellaria³ rotunda (Dall)
 Jouannetia sphaeroidalis (Guppy)
 Martesia bowdeniana (Dall)
 Xylophaga ? species
 Teredo ? species

The preceding list shows a total of 610 species, subspecies, and varieties of mollusks as follows:

Species, subspecies, and varieties of mollusks from Bowden formation

Gastropods	406
Scaphopods	20
Pelecypods	184
Total	610

Of these 47 represent gastropods of the families Pyramidellidae and Melamellidae that are not described; three represent Rissoids that are not named even generically; and 75 are not given specific names, leaving a total of 485 named species, three of which are pelecypods not considered in Publication 366 (*Chlamys nodosus* (Linné), *Antigona caesarina* (Dall), and *Chione granulata* (Gmelin)). The pelecypods probably are somewhat overnamed.

It is apparent from the preceding list that the Bowden fauna is a very remarkable one, perhaps the most remarkable that has so far been found in America. No other American Tertiary locality has yielded 600 species of mollusks. The Bowden locality gives a more complete representation of the total number of shell-bearing mollusks than is generally found at American Tertiary localities. Dall's early estimate (U. S. Geol. Survey Bull. 84, p. 27, 1892; U. S. Fish Comm. Bull. 1900, vol. 1, p. 354, 1901) of 600 species for a tropical fauna is far too low. Perhaps 1000 species would be a modern estimate of the total number of shell-bearing mollusks that would be expected in

¹ *Solecuretus* Blainville, 1824, Dict. Sci. Nat., vol. 32, p. 351; type, by subsequent designation Deshayes, Dict. Class. Hist. Nat., vol. 15, p. 482, 1829 (quoted from Iredale, Proc. Malac. Soc. London, vol. 11, p. 306, 1915), *Solen strigilatus* Linné.

² See Gardner, Nautilus, vol. 40, No. 2, pp. 41-47, 1926.

³ *Rocellaria* Blainville, 1828, Dict. Sci. Nat., vol. 57, p. 244; type, by monotypy, *Gastrochaena modiolina* Lamarck (= *Mya dubia* Pennant). (See Iredale, Proc. Malac. Soc. London, vol. 11, pp. 296-297, 1915.)

the West Indies in a strip covering every ecologic niche from the shore to a depth of about 100 fathoms and also embracing the pelagic species. On the basis of this estimate the Bowden fauna as now known is only 60 per cent complete. It is not difficult to point out some of the gaps. The rock-clinging, rock-boring, and mud-burrowing species are almost entirely unrepresented. The following genera, which according to current age determinations were living in the Caribbean region during the time when the Bowden formation was deposited, so far are unrepresented in the Bowden fauna:

*Caribbean middle Miocene genera so far unrepresented in Bowden formation*¹

Gastropods:

Limacina	Mitra s. s.	Botula
Vaginella	Vasum	Lithophaga
Styliola	Dolicholaturus	Crenella
Rictaxis	Galeodes	Pholadomya
Abderospira	Peristernia	Cyathodonta
Haminoea	Solenosteira	Pandora
Carinaria	Northia	Coralliophaga
Fusoterebra	Nitidella	Pseudochama
"Clavatula" (labiata	Sistrum	Lucinisca
Gabb)	Cymia	Miltha s. s.
Knefastia	Morum	Thyasira
Gemmula	Cypræacassis	Montacuta
Leucosyrinx	Pustularia	Lophocardium
"Drillia" (squamosa	Siliquaria	Dosinia
Gabb)	Torinia	Clementia
Borsonia	Crepidula	Macrocallista
"Bivetia"	Crucibulum	Petricola
Narona	Calyptrea	Tellidora
Aphera	Turgurium	Metis
Agaronia	Neverita	Sanguinolaria
Glabella		Tagelus
Prunum	Pelecypods:	Solen
Egouana	Acila	Harvella
Bullata	Adrana	Mactrella
Persicula	Cunearca	Micromactra
Voluta	Senilia	Mulinia
Lyria	Noetia	Raeta
Enaeta	Dimya	Mesodesma
Aurinia	Mytilus	Panope
Halia	Modiolus	

No locality, however, is going to yield a complete fauna, for it is inconceivable that mollusks representing every ecologic niche could be brought together at one place by natural means.

¹ In this list, as in others, subgenera and sections are for convenience given the same rank as genera.

Despite the gaps in the Bowden fauna it is remarkable for the unusual representation of several families (particularly the Turridae, Conidae, Mitridae, Pyrenidae, Rissoinidae, Naticidae, Epitoniidae, Trochidae, Fissurellidae, Arcidae, Pectenidae, Lucinidae, and Tellinidae), and for the large number of genera that have not yet been found elsewhere in the Miocene deposits of tropical America. These genera are as follows:

Bowden genera not yet found elsewhere as Miocene fossils in tropical America

Gastropods:

Tralia	Janthina	Rimula
Siphonaria	Mathilda	Hemitoma
Williamia	Leptothyropsis	Acmaea
Vaughanites	Otollonia	
Mitromorpha	Coanollonia	Pelecypods:
Seguenzia	Clypeolum	"Nuculopsis"
Cerithiopsis	Dentistyla	Tindaria
Dizoniopsis	Antillachelus	Obliquarca
Seila	Mirachelus	Ovalarca
Planaxis	Microgaza	Bowdenia
"Gottoina"	Cocculina	Myrteopsis
Psilaxis	Fissurella	Pliocardia
Spirolaxis	Lucapina	Cooperellopsis
Mirarissolina	Lucapinella	Elliptotellina
Eurissolina	Fissurisepta	Jouannetia
Cycloscala	Emarginula	

Of the genera in the preceding list the following are not recorded at any other American Tertiary locality:

Bowden genera not yet found elsewhere as Tertiary fossils in America

Gastropods:

Tralia	Janthina	Pelecypods:
Siphonaria	Leptothyropsis	"Nuculopsis"
Williamia	Otollonia	Tindaria
Vaughanites	Coanollonia	Obliquarca
Seguenzia	Dentistyla	Ovalarca
Planaxis	Antillachelus	Bowdenia
Spirolaxis	Mirachelus	Myrteopsis
Mirarissolina	Microgaza	Pliocardia
Eurissolina	Cocculina	Cooperellopsis
Cycloscala	Fissurisepta	Elliptotellina
		Jouannetia

ANALYSIS OF GENERA

Most of the Bowden genera are still living in West Indian waters, but a number are living elsewhere and about the same number are extinct. The living exotic genera, which are now found in the Pacific Ocean, are as follows:

Pacific exotic genera in Bowden fauna

Gastropods:		Scaphopods:
Fusiturricula	Talityphus	Tesseracme
Dendroconus	Malea	
? Tribia	Talparia	Pelecypods:
Dactylidella	Ochetoclava	Placunanomia
Strombina	? Eurissolina	Julia
Metula	Eunaticina	Jouannetia
? Typhinellus	Clypeolum	

In addition, the following species have living analogues in the Pacific, but not in the Caribbean Sea:

Bowden species and analogous living Pacific species unrepresented in Recent Caribbean fauna

BOWDEN SPECIES	ANALOGOUS LIVING PACIFIC SPECIES
Acteon textilis Guppy	A. traskii Stearns
Terebra species	T. robusta Hinds
Cancellaria laevescens Guppy	C. obesa Sowerby
Strombina caribaea Gabb	S. gibberula (Sowerby)
Rissoina species	R. mexicana Bartsch

The following genera seem to be extinct:

Extinct genera in Bowden fauna

Gastropods:	Mirarrissoina	? Obliquarca
Globidrillia	Pachycrommium	Ovalarca
Scobinella	Otollonia	Bowdenia
Vaughanites	Coanollonia	Myrteopsis
Engoniophos		Pliocardia
? Eurypyrene	Pelecypods:	Cooperellopsis
Metulella	? "Nuculopsis"	Bothrocorbula
? Cigclirina	? Pseudoportlandia	

Acteocina coixlacryma Guppy, which perhaps should be given a subgeneric name, represents an extinct phylum of Acteocinas.

On the basis of these lists and disregarding the question marks and the undescribed families, about 89 per cent of the Bowden genera are still living in the West Indian region, 5 per cent are exotic Pacific genera and 6 per cent are extinct. These figures are only approximate, for aside from the doubt about some of the genera listed, the Rissoidae, Melanellidae and Pyramidellidae are not considered, and it is not certainly known whether all the turrid genera except those listed are living West Indian genera.

ORIGIN OF THE BOWDEN FAUNA

It is not possible at the present time to trace the history of the genera represented in the Bowden formation. *Ancistrosyrinx*, *Microdrillia*, *Scobinella*, *Uromitra*, *Sigatica*, *Pachycrommium*, and *Elliptotellina* are outstanding Eocene survivors. Other Eocene genera are represented, but a modern revision of the Eocene mollusks of the Gulf coast of the United States would be required for an adequate comparison to supplement the rather meager Caribbean Eocene faunas. Likewise the mollusks of the Vicksburg group are needed to supplement the records of Caribbean Oligocene species. Lower Oligocene mollusks have not been recorded anywhere in the Caribbean region, unless the few species from Guallava, Costa Rica, collected from beds carrying *Lepidocyclina hilli* Cushman, and the "*Lucina*" *megameris*-bearing beds of Jamaica represent that stage. According to current age assignments, the Red Bluff formation of Mississippi should afford a means of tracing some of the Bowden genera during lower Oligocene time. Antigua and Porto Rico are the only localities in the Caribbean region that have yielded a considerable number of Oligocene mollusks and at these localities the beds are placed in the middle Oligocene. The Antigua mollusks, consisting of 26 recorded species, half of which are Pectens, are principally reef-dwellers. Those from Porto Rico represent a greater ecologic range, but most of the material is poorly preserved. They give an indication, however, of what might be expected from an Oligocene fauna as large as the Miocene ones. The unnamed Porto Rican *Xancus* is the earliest species from America. The Porto Rican *Hyphantosoma* far antedates the next younger species, which is of middle Miocene age. *Clementia dariena rabelli* Maury carries over the record of the *dariena* phylum from Eocene to Miocene. No marine upper Oligocene Caribbean mollusks are on record, unless some of the beds referred to the lowermost Miocene are upper Oligocene. The Byram marl of Mississippi (top formation of Vicksburg group), which is placed in the upper Oligocene, bridges over this gap. It carries many species that undoubtedly are the predecessors of those in the West Indian and Florida Miocene, including the earliest American species of *Distorsio* s. s. and *Sconsia* s. s., and the earliest *Xancus* on the American mainland. A great many Byram genera—among them *Acteocina*, *Crassispira*, *Ancistrosyrinx*, *Microdrillia*, *Scobinella*, *Uromitra*, *Vexillum*, *Xancus*, *Latirus*, *Distorsio*, *Semicassis*, *Sconsia*, *Ficus*, *Lucina*, *Myrtaea*, "*Acanthocardia* ?," and *Abra*—are found in the Bowden formation. Before the Miocene species from tropical America were known it was supposed that *Scobinella* disappeared after Byram time. Though the Byram marl carries many forerunners of Miocene species it has Eocene survivors

in the genera known as *Pleuroliria*, *Pleurofusua*, *Microsurcula*, *Bathytoma*, *Conorbis*, *Clavilithes*, and *Aporrhais*, but *Ampullinopsis* gives it an Oligocene stamp.

Beginning with the lower Miocene many of the Bowden genera and species can be traced in the Carribean and Florida faunas of the Anguilla, Tampa, Thomonde, Chipola, and Cercado horizons. The Carribean Miocene faunas seem to represent an abrupt invasion, but such an impression is erroneous and is due to the scarcity there of records of Oligocene mollusks. When more complete data are available it probably will be found that the bulk of the Bowden species represent autochthonous Oligocene and Miocene phyla and that a few are due to increments from the Mediterranean and from the eastern Pacific.

ECOLOGY OF THE BOWDEN MOLLUSKS

TEMPERATURE

It hardly need be remarked that the Bowden fauna is tropical. Both its size and composition, as well as its location show that. Yet it probably would be richer than the present West Indian fauna if it were fully known, for the present fauna is strikingly impoverished in terms of the middle Miocene fauna. The most dramatic event in the history of the West Indian fauna is the wholesale disappearance of genera at and soon after the close of Miocene time. Genus after genus, many of which are now living on the other side of Central America, then became extinct there and relatively few genera have taken their place. I hope at some future time to assemble the comparative data and to discuss this matter more fully. The significance of this event, which was well known to the pioneers in West Indian palaeontology, must still be left open. Inasmuch, however, as similar events in other parts of the world, such as the disappearance of tropical genera in the Mediterranean Sea early in the Pleistocene (Calabrian) and the reappearance there of a warm fauna in the *Strombus bubonius* fauna during the second interglacial stage, corresponding to the Chellian interglacial fauna of northern Europe, have a temperature significance, it seems to be a reasonable working hypothesis that the change in the West Indian fauna is due to a change in the temperature of the water, for no other reasonable hypothesis is apparent. Also inasmuch as the disappearance of these genera followed the closing of the channels across Central America that permitted free communication between the Caribbean Sea and the Pacific, and as many of the genera are still living on the Pacific coast of Central America, the change seems to be due at least in part to a change in oceanic circulation resulting in the exclusion of Pacific water from the Caribbean. This conclusion opens up a complex problem in which the many factors that determine the range of marine mollusks and other animals need consideration. According to studies of the life history of mollusks of economic importance, the temperature of the water during the reproductive period probably is the most important factor determining the northward range of species in the northern hemisphere. Unless the temperature reaches a certain minimum during the spawning season, spawning fails to take place or takes place abortively. Whether the change in oceanic circulation in the Caribbean Sea would result in a lowering of the temperature of the water there and whether it would be lowered enough to be effective as a factor in temperature selection is at the present time a matter of speculation, but this aspect deserves consideration (see Woodring, Jour. Washington Acad. Sci., vol. 16, No. 3, p. 77, 1926). Though a change in temperature

of the water may be the principal factor, the presence of at least two of the genera (*Cymia* and *Placunanomia*) as far north during Miocene time as New Jersey and North Carolina, respectively, shows that the problem is not so simple and that other factors must be considered. At all events if number of genera and species is a measure of temperature, the Caribbean Sea during the time when the Bowden formation was deposited was at least as warm as it now is.

SALINITY

Aside from a few species the Bowden mollusks are such as live in the open sea in water having only a slight range of salinity. According to the testimony of modern species belonging to the same groups, the two species of *Neritina*, the *Mytilopsis*, and the oyster (*O. folioides*) similar to the American mangrove oyster are the only ones that lived in brackish water. Many of the specimens of *Neritina* are badly corroded like Recent fresh-water or brackish-water shells. The absence of *Galeodes*, *Potamides* and other cerithioids, *Senilia*, and *Corbicula*, all of which prefer or tolerate brackish water and are found in middle Miocene deposits elsewhere in tropical America, as well as of fresh-water genera, indicates that very little brackish-water material had access to the locality where the part of the Bowden formation that has been explored was laid down. Yet the *Neritinas* are represented by too many specimens (18 of *N. woodwardi* and three of *N. pterota* in the Henderson collection, 25 and nine, respectively, in the Duerden collection) to dismiss them as "fortuitous." Somewhere near by a stream entered the sea, in the estuary of which these brackish-water species lived. These shells could not have lived with the marine species among which they now are found, but their presence apparently is to be attributed to unusual events, perhaps unusually heavy floods, for otherwise additional brackish-water genera should be represented.

CHARACTER OF BOTTOM

Records of shore collecting and of dredging operations must be relied on to furnish the data to be used in drawing any conclusions as to the character of the bottom on which the Bowden mollusks lived, and the records should deal with the American tropics to be of the greatest value. Records of shore collecting are scattered through a mass of literature, though by this time some of the data has filtered through to the manuals and the books on the natural history of the seashore. It was expected that the "Catalogue of shells collected at Panama" (334 pp., New York, 1852), by C. B. Adams, would be particularly useful, for it represents the remarkable achievement of collecting and recording the habitat of 41,800 specimens of 516 species of mollusks all within a period of a little more than a month. It is the most detailed account now available of the habitat of marine

mollusks in the American tropics. Conditions for shore collecting are very favorable in Panama Bay on account of the tidal range of 16 to 20 feet and on account of the variety of habitats. It is precisely the unusual tidal range, however, that is responsible for the finding of most of the active gastropods under stones, where they retire to await the return of the tide. It would be faulty to assume that the Bowden species of all these genera also lurked under or among stones, for in the Caribbean region most of these genera now are not exposed by the slight fall of the tide, and there is no reason to believe that the tidal range was any greater when the Bowden formation was deposited. The little book published anonymously by Krebs (The West-Indian marine shells, 137 pp., Copenhagen, 1864) is the only general account for the West Indian region that I know of. Records of modern dredging operations at moderate depths (less than 100 fathoms) are not available for either the West Indian or Panamic regions. Stations are not recorded under the species in the report on the mollusks of Porto Rico (Dall and Simpson, Bull. U. S. Fish Comm., 1900, vol. 1, 524 pp., pls. 53-58, 1901), though the character of the bottom is recorded in a list of the stations (p. 514). Records derived from the ordinary run of dredging operations are not entirely trustworthy, however, unless the hauls are numerous and of short duration. The dredge generally is dragged over too large an area, and on hard bottoms it misses the burrowers. The results of reoccupying more than 100 stations during the survey of the Woods Hole region may be taken as an example. Types of bottoms identical with the original record were recorded in only 14 per cent of these reoccupied stations. Only an additional 33 per cent were substantially identical, whereas in 6 per cent the record was totally different (Sumner and others, Bull. Bur. Fisheries, vol. 31 (1911), pt. 1, p. 31, footnote, 1913). Reliable data as to the bottom and as to the composition of animal communities on the bottom probably will not be available to serve as a basis for interpreting a West Indian Miocene fauna until some type of grab is used at moderate depths in the Caribbean region. (For the use of a grab and its results see Petersen, Rept. Danish Biol. Station, No. 20, pp. 47-50, 1911; Annal. Inst. Océanographique, vol. 6, No. 1, 13 pp., 10 figs., 1913; Proc. Zool. Soc. London, 1924, pt. 2, pp. 687-694. Sumner and others, California Univ. Pub. Zoology, vol. 14, p. 7, 1914. Packard, California Univ. Pub. Zoology, vol. 18, pp. 299-333, pls. 12-13, 6 figs., 1918. Davis, Great Britain, Ministry Agr. and Fisheries, Fishery Invest., ser. 2, vol. 6, No. 2, 54 pp., 11 figs., 1923. Stephen, Fishery Board for Scotland, Sci. Invest., 1922, No. 3, 21 pp., 2 charts, 1923.)

So far as the Bowden fauna is concerned the evidence as to the character of the bottom is partly negative and therefore not worth very much. There are hardly any mollusks that cling to rocks or bore in rocks. *Chlorostoma*, represented by three small badly broken

specimens, and *Thais*, represented by one very small specimen, seem to be the only intertidal rock-clingers. *Sistrum*, *Tectarius*, *Echinella*, *Littorina*, *Cittarium*, *Nerita*, large limpets, and large limpet-like pulmonates are absent. Both limpets and limpet-like pulmonates (*Acmaea* and *Siphonaria*, respectively) are represented at Bowden, but the shells are very small and resemble modern species that cling to sea weeds rather than to rocks. It is not known, however, whether all the other genera in the preceding list were living in the West Indian region during middle Miocene time, *Sistrum* being the only one for which there is any record. The others may have been living then, or if not some other genera took their place and they probably would be recognized as rock-clingers. The keyhole limpets have an unusually full representation in the Bowden fauna, but they generally live below low-water mark and cling to sea weeds as well as to rocks, and are also found under stones. It should be noted that rock-clinging species are very rare as Miocene fossils in the whole Caribbean region. Perhaps special conditions are necessary to preserve such shells, for they may be ground to pieces or dissolved before they can be buried. That they may be preserved is shown, for example, by the presence of *Tectarius*, *Littorina*, *Cittarium*, and *Nerita* in the Pliocene beds at Port Limon, Costa Rica.

Rocellaria, *Jouannetia*, and *Martesia* are the only rock- or coral-boring bivalves. *Lithophaga*, *Coralliophaga*, *Petricola*, *Saxicava*, and *Pholas* are unrepresented, though they are much more common as Miocene fossils in this region than the rock-clinging snails. Nevertheless, some of these genera probably were living at Bowden, for corals at least were there for them to bore. Even disregarding the records for Panama Bay many of the predaceous carnivores among the Bowden gastropods belong to genera (*Conus*, *Mitra*, *Vexillum*, *Murex*) that lurk beneath or among stones and in the labyrinths of coral reefs. Also some of the bivalves (*Arca* and *Lima*) make nests between stones, and others (*Fossularca*, *Spondylus*, *Plicatula*, *Chama*) are found on stones or corals. Possibly, however, the only "stones" were pieces of dead coral. It seems strange that the Calyptraeidae, which attach themselves to stones and to other shells, is represented only by the genus *Cheilea*.

The great abundance of *Oliva*, one species of which is represented by about 1000 specimens in the Duerden collection, and of *Olivella* conclusively shows that sand flats contributed to the Bowden fauna. Recent species of both these genera may be seen crawling about on intertidal sand flats. Adams (pp. 57 to 58), who collected 4500 specimens of "*Olivella*" *volutella* (Lamarck) at Panama, reports that this species crawls about very actively on the wet sand when the tide is out. The shell is covered with the mantle and the mantle is concealed by a thick coat of wet sand. When the returning tide washes off the

coat of sand these snails quickly bury themselves. The naticoids, which are represented at Bowden by a large number of species and specimens, prefer sandy places. They plow about in the sand, using the modified fore part of the foot as a plow and shield, searching for the bivalves on which they prey. Most of the burrowing bivalves are recorded from sandy bottoms, or from mixtures of sand and mud, and of sand and gravel. Perhaps the absence of *Clementia* and *Mulinia* indicates that no extensive mud flats were near by.

I had hoped to list the probable bottom habitat and depth range of the Bowden genera that are still living, but the data that were assembled are not precise enough and fail to cover the entire field. The Bowden fauna is too large to represent only one kind of bottom. So far as the burrowing bivalves and some of the carnivorous gastropods are concerned it seems to represent principally sand, and mixtures of mud, sand, and gravel. Some of the bivalves nest among stones, others are attached to stones and coral. Many of the carnivorous gastropods lurk among stones. The plant-feeders among the gastropods are for the most part independent of the bottom, except in so far as it controls the growth of plants. Some of the carnivores (*Corallophila* and *Cypraea*) browse principally on corals, and *Simnia* is peculiarly modified to crawl about on the narrow rounded stems of gorgonians, on which it feeds. The negative evidence as to the rock-clingers, rock-borers, and mud-burrowers may not be significant.

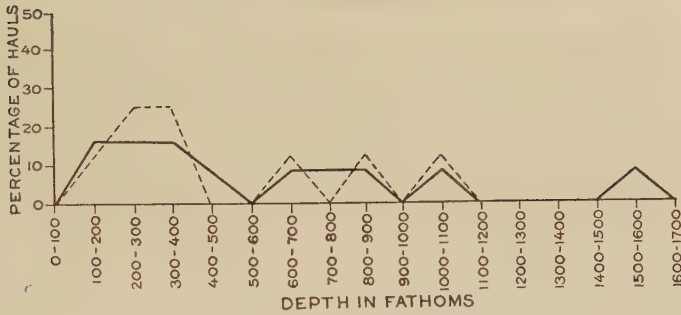
DEPTH

Tralia and *Planaxis* are the only mollusks at Bowden whose modern representatives are amphibious and habitually live between high- and low-water marks or even above high-water mark. Adams (p. 210) found *Tralia panamensis* under stones at high-water mark, or crawling about over wet stones. *Chlorostoma* and *Thais* seem to be the only rock-clinging mollusks that live in the intertidal zone and also below the low-water mark. Some of the sand-facies species (*Oliva*, *Olivella*, *Natica*) may also be found on sand flats that are exposed during low tide.

It is apparent from a glance at the faunal list that most of the Bowden mollusks represent the neritic zone, or the zone from low-water mark to a depth of 200 meters, or about 100 fathoms. A few

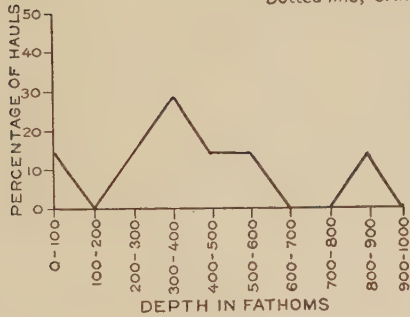
EXPLANATION OF FIGURE 1 (see page 33)

- A. 8 hauls of *S. monocyngulata* Seguenzia, and one each of *S. ionica* Watson, *S. carinata* Watson, *S. floridana* Dall, and *S. watsoni* Dall.
- B. 3 hauls of *C. rathbuni* Dall, 3 of *C. reticulata* Verrill, and one of *C. pocillum* Dall.
- C. 3 hauls of *Puncturella acuminata* Watson, and 2 of *P. circularis* Dall.
- D. 3 hauls of *T. acinula* Dall, 3 of *T. amabilis* Dall, 2 of *T. smithi* Dall, and one each of *T. cytherea* Dall, and *T. lata* Verrill and Bush.
- E. 7 hauls of *B. glomerula* (Dall), 3 of *B. oribiculata* (Dall), 3 of *B. polycyma* (Dall), and 3 of *B. pectunculoides* (Scacchi).
- F. 8 hauls of *Vexillum styria* (Dall).

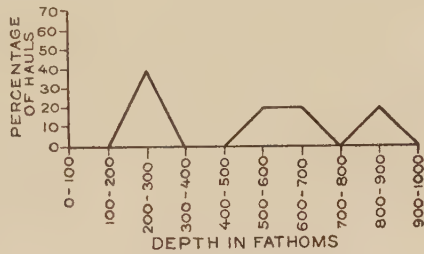


A. SEGUENZIA

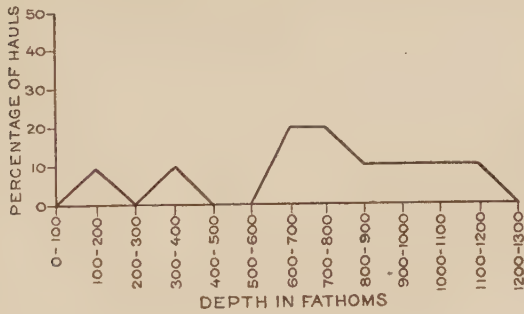
Dotted line, *S. monocingulata* (Seguenza)



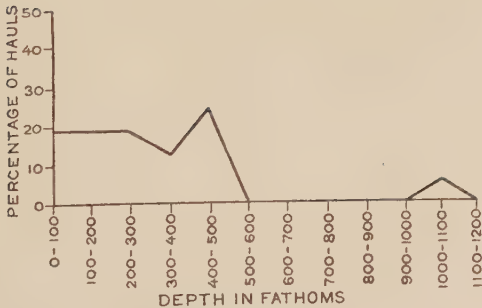
B. COCCULINA



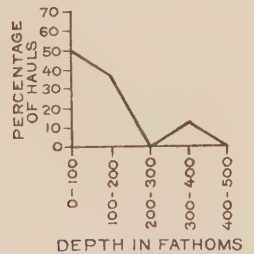
C. FISSURISEPTA



D. TINDARIA



E. BATHYARCA



F. UROMITRA

FIG. 1.—Depth frequency graphs for several Bowden genera, based on dredging records of Recent species in West Indian and Florida regions and Gulf of Mexico.

genera, however, were suspected of representing deeper water. In order to test out their probable depth significance the depth frequency graphs shown in fig. 1, based on specimens in the National collections dredged in the West Indian and Florida regions and in the Gulf of Mexico, were plotted. In compiling these records a station was used only once in any genus, though in several genera two species were identified from the same haul. Along the Atlantic coast of the United States, which lies outside the area considered, *Seguenzia* has been dredged at depths of 1290 to 2033 fathoms, *Cocculina* from 17 to 2033 fathoms, and *Tindaria* at 2620 fathoms. *Uromitra* (F of fig. 1) was chosen at random to represent an essentially shallow-water genus, records for which are based on almost the same number of dredge hauls as the average of the others.

On the assumption that during middle Miocene time these genera lived at the same depth as now and that the dredging records are sufficiently numerous to be safely used, these graphs clearly show that *Seguenzia*, *Fissurisepta*, and *Tindaria* represent a probable depth of more than 100 fathoms. Despite its remarkable range of 90 to 880 fathoms (17 to 2033 along Atlantic coast) *Cocculina* probably should be placed in the same class. *Bathyarca* does not necessarily mean deep water, even though it has been dredged in the West Indian region at depths as great as 1024 fathoms. The frequency graph for *Bathyarca* (E of fig. 1) shows that the maximum, which falls between 400 and 500 fathoms, does not represent a very much larger percentage of the hauls than the interval between low-water mark and 100 fathoms. Along the Atlantic coast of the United States *Bathyarca* is represented in hauls from 5 to 1825 fathoms. It also may be significant that *Seguenzia*, *Cocculina*, *Fissurisepta*, and *Tindaria* have not been found fossil at any other locality in America, whereas *Bathyarca* is not so rare.

The probable deep-water genera are represented in collections from Bowden by the following number of specimens:

Number of specimens of probable deep-water genera in collections from Bowden formation

Genus	Duerden collection	Aldrich collection	Henderson collection
<i>Seguenzia</i>	1	67	—
<i>Cocculina</i>	11	15	2
<i>Fissurisepta</i>	1	—	—
<i>Tindaria</i>	1	—	—

These genera are very small, and if all of them were represented by only one specimen, as two of them are, it would be necessary to consider seriously that they might have been eaten by fish in deep water and

then discharged in shallower water. But to account for 68 and 28 specimens by such means is fantastic.

The adequacy of the dredging records on which the frequency graphs are based is, however, open to suspicion. The records for *Bathyarca* show that a genus may have a remarkable depth range and a few shallow-water records for the other genera would completely change their depth significance. Genera that are considered deep-water dwellers are constantly being found in relatively shallow water. Dredgings by the *Fish Hawk* in Porto Rican waters at depths of less than 100 fathoms brought up a number of species that had been known only from hauls made by the *Blake* in deep water (Dall and Simpson, U. S. Fish Comm. Bull. 1900, vol. 1, p. 354, 1901).

Other factors than dredging records need consideration. The relatively large number of carnivores among the gastropods is a striking feature of the Bowden fauna, the great number of turrids, cones, and mitroids being particularly noteworthy. The most reasonable explanation for this discrepancy is that part of the fauna lived in relatively deep water, in the aphotic zone where the animals feed on fresh flesh or carrion, or are mud-eaters.

The relatively large number of pelagic mollusks, consisting of five species of pteropods, two of heteropods, and one of *Janthina*, may have the same depth significance. This is the largest number of species of pelagic mollusks that has been found anywhere in America and two of the pteropods are represented by almost a hundred specimens each in the Henderson collection. The Pteropod marl of the early Jamaican Survey (Sawkins and others, Reports on the geology of Jamaica: Mem. Geol. Survey [Great Britain], p. 46, 1869) may represent a concentrate of pelagic shells in the upper part of the Bowden formation.

According to the preceding discussions, mollusks that live in brackish-water estuaries, in the littoral zone, in the neritic zone, and also in water perhaps more than 100 fathoms deep are found mixed together at Bowden. How to reconcile such a depth range without field studies is largely a matter of speculation. It naturally is more reasonable to believe that the intertidal and shallow-water species were moved downward than that the deep-water species were moved upward. There are too many kinds of shallow-water shells among the gastropods to attribute their present location to the activities of hermit crabs. Aside from the variety of shallow-water gastropods and the presence of shallow-water pelecypods, the probable range of depth at Bowden is too great to admit hermit crabs to consideration. Most of the shallow-water shells are too fresh to have been carried far by waves or currents. The Bowden formation occupies only a narrow strip along the coastal edge of the White Limestone. In the absence of field evidence to the contrary, it is conceivable that it represents deposition along an unusually steep slope in which a narrow coastal shelf

was cut and that at times the sediments at the edge of the shelf and the shells buried in them were washed down the slope and came to rest at a greater depth, where they were mixed with the autochthonous material. Unusually steep slopes are to be expected in regions of active tectonic movements. All this is admittedly a matter of speculation, and it is hoped that it can eventually be tested in the field. The configuration of the pre-Bowden surface of the White Limestone, the presence or absence of crumpled layers in the Bowden formation and of layers containing only deep-water genera and pteropods alternating with layers carrying only shallow-water genera or a mixture of both, and the character of the sediments—all should yield evidence to test the indicated depth range. Dredging operations along some of the remarkably steep slopes in the West Indian region that lie only a short distance off shore would yield essential data.

It should be pointed out that both the corals and foraminifera yield results that may be interpreted in the same way as the mollusks. According to Vaughan (U. S. Nat. Mus. Bull. 103, p. 212, 1919), the Bowden corals indicate deeper water than other Miocene and Oligocene faunas in the Caribbean region and Florida, but some of the species furnish evidence that the depth was not so great as 20 fathoms. Cushman (Carnegie Inst. Washington Pub. 291, pp. 28–29, 1919) concluded that the foraminifera indicate a considerable depth, even if it were less than 100 fathoms. Both these estimates may represent an attempt to strike an average from the evidence of both shallow- and deep-water forms.

BORING GASTROPODS

The neatly rounded holes that can be seen on many of the photographs of both gastropods and pelecypods are evidence of the activities of some of the predaceous carnivorous gastropods, for it is well known that these holes are drilled by other mollusks. The method consists of selecting a place where the shell is relatively thin, generally on the beaks of bivalves and on the upper whorls of gastropods, and drilling the hole by patiently scraping with the radula. After the hole is bored the proboscis is inserted into the shell and the victim is leisurely devoured. Along the Atlantic coast of the United States the moon shell (*Lunatia heros* (Say)) and the oyster drill (*Urosalpinx cinereus* (Say)) are the worst offenders. Other genera, including *Buccinum*, "*Nassa*," *Murex*, and *Thais* are known to secure their food in this manner or are suspected of it. The relative number of drilled shells in each species of gastropods in the Henderson collection was tabulated in order to discover whether the genera responsible for this work at Bowden could be discovered. Of the carnivores that need to be considered *Conus*, *Murex*, *Nassarius*, and *Strombus* have the smallest percentage of bored shells, as follows:

Percentage of bored shells in several genera of predaceous carnivores

Genus	Percentage
<i>Conus</i>	16
<i>Murex</i>	10
<i>Nassarius</i>	6
<i>Strombus</i>	7

Strombus has never been accused of boring shells; in fact, it is supposed to be a carrion-feeder. It is well known, however, that it is very active and powerful. The percentage of bored shells in *Conus* is relatively high, but all the perforated shells belong to small species or are young specimens of large species. Doctor Pilsbry informs me that the teeth of the cones he has examined are very delicate and quite unsuited for boring. *Conus* apparently attacks only extended mollusks and paralyzes them with its powerful poison. So far as *Strombus* and *Conus* are concerned the small percentage of bored shells is a measure of aggressiveness rather than of boring. Perhaps *Murex* and *Nassarius* are responsible for most of the holes, but the worst offender may be concealed, as some of the borers are suspected of cannibalism. For some unknown reason the Terebras show the highest percentage of bored specimens, 75 per cent of them being bored. In three of the species of *Strioterebrum* all the shells are bored. Moreover, in one of these species (*T. monida*) all the shells have more than one hole, one having as many as eleven. Apparently more than one animal operated on these Terebras at the same time, for it is improbable that any gastropod would bore an empty shell. This conclusion points to a small animal, possibly *Nassarius*, as responsible for the holes, at least in *Terebra*.

SUMMARY AS TO ECOLOGY

In this discussion of the ecology of the Bowden mollusks more weight has been given to depth of the water than to any other factor. Perhaps depth in itself is not very significant, as the controlling factor may be disguised because it has not been separated from the depth factor in dredging operations. The ease with which depth can be determined in dredging, the accessibility of dredging records giving the depth, and above all the very limited number of records from shallow water in the West Indian region, may conspire to give depth an importance out of all proportion to its actual significance. Nevertheless, the relative abundance of pelagic shells and the large proportion of carnivorous gastropods indicate, aside from the doubtful evidence based on dredging operations, that some of the Bowden mollusks represent deep water. It is conceivable that under special conditions pelagic shells would accumulate in great numbers in shallow water and that an unusually large proportion of carnivores would live in shallow water, but when it is necessary to postulate special condi-

tions for each of several converging lines of evidence the simpler explanation is more reasonable. In the light of available data the conclusion that the Bowden fauna is an ecologic mixture so far as depth is concerned seems justified.

Other ecologic factors, aside from those discussed, that need consideration are omitted, either because no relevant data, based on the ecology of modern mollusks, could be found, or because it would be difficult to recognize the effects of such factors. It also should be remembered that I have never been at Bowden. Consequently the character of the sediments and other features that must be based on field observations are perforce ignored. The result of all this is to make this account of the ecology unsatisfactory and inconclusive.

The outstanding feature of the Bowden fauna is that it seems to represent an unusual ecologic range especially as to depth. It probably is this unusual range that makes the fauna so large and that makes it the most remarkable Tertiary fauna in tropical America.

AGE OF THE BOWDEN FAUNA

COMPARISON WITH MIOCENE FAUNAS ELSEWHERE

TROPICAL AMERICA

STANDARD TERTIARY SECTION FOR TROPICAL AMERICA

The following composite section, which may be regarded as the present standard Tertiary section for tropical America, is based on stratigraphic and faunal data, but principally on the latter. It represents current interpretations and will inevitably be modified.

At the present time the lower and upper Oligocene and Pliocene parts of this section are in the most unsatisfactory state. It will also be noted that the Miocene part includes almost as many zones as all

Standard Tertiary section for tropical America

Time subdivision		Formation names and localities of unnamed deposits	Supposed European equivalents
PLIOCENE		Near Port Limon, Costa Rica; Matura, Trinidad; near Jacmel, Republic of Haiti	Astian Plaisancian
MIOCENE	Upper	Cerros de Sal formation, Dominican Republic; Springvale, Trinidad	Pontian Sarmatian
	Middle	Bowden formation, Jamaica; upper zone of Gatun formation, Panama and Costa Rica Gurabo formation, Dominican Republic; lower and middle zones of Gatun formation, Panama Canal Zone, and lower zone of Gatun formation, Costa Rica Cercado formation, Dominican Republic	Tortonian Helvetian
	Lower	Thomonde formation, Republic of Haiti; Baitoa formation, Dominican Republic; Quebradillas limestone, Porto Rico Anguilla formation, Anguilla; upper part of Culebra formation and Emperador limestone, Panama Canal Zone	Burdigalian Aquitanian
OLIGOCENE	Upper	? Upper part of Antigua formation, Antigua	Chattian
	Middle	Lower part of Antigua formation, Antigua	Rupelian
	Lower	? Limestone in Republic of Haiti and Jamaica	Lattorfian
EOCENE	Upper	St. Bartholomew limestone, St. Bartholomew; Bontour Point, Trinidad	Priabonian
	Middle	Yellow limestone, Jamaica; Plaisance limestone, Republic of Haiti	Auversian Lutetian
	Lower	Soldado Rock and Marac Quarry, Trinidad	Ypresian Thanetian

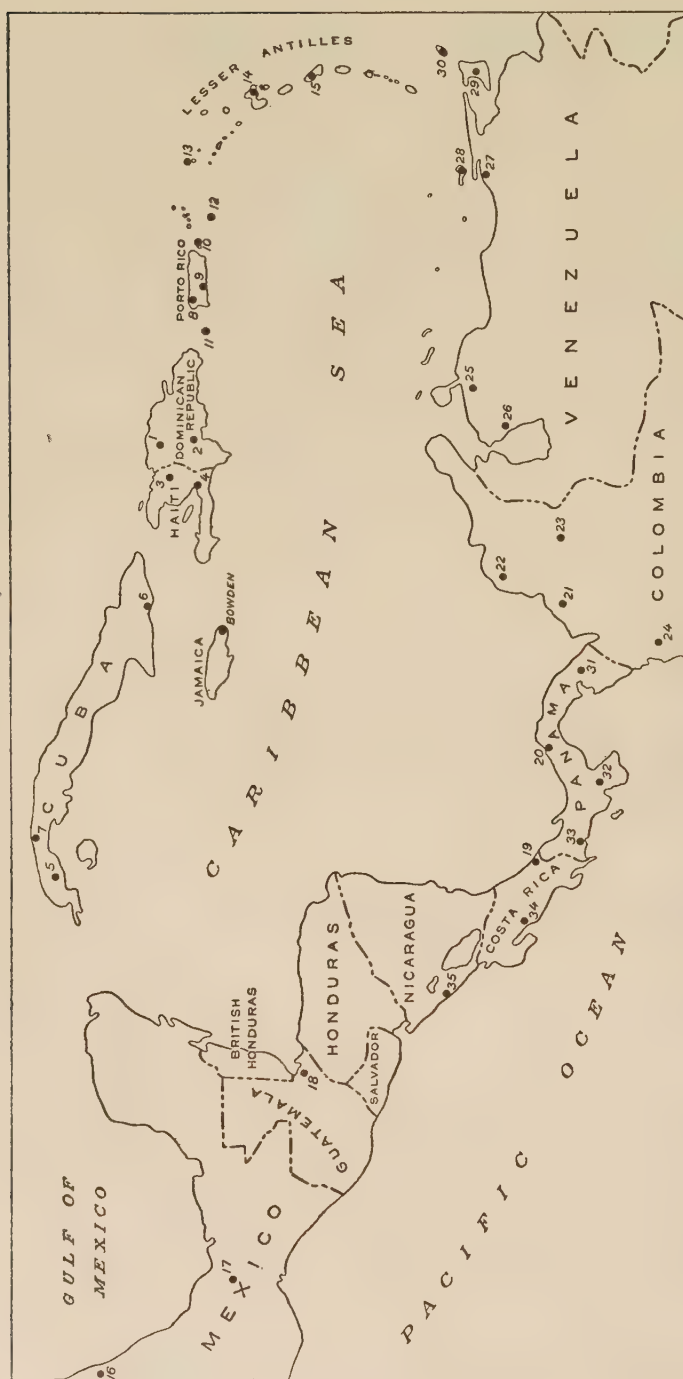


Fig. 2.—Sketch map showing Miocene localities in tropical America.

1. Yaque Valley, Dominican Republic.
2. Yaque del Sur Valley and Henriquillo Basin, Dominican Republic.
3. Central Plain, Republic of Haiti.
4. Port-au-Prince, Republic of Haiti.
5. Consolación del Sur, Cuba.
6. Santiago, Cuba.
7. Havana, Cuba.
8. Northern Porto Rico.
9. Southern Porto Rico.
10. Vieques.
11. Mona.
12. St. Croix.
13. Anguilla.
14. Martinique.
15. Tampico embayment, Mexico.
16. Isthmus of Tehuantepec, Mexico.
17. Guatemala.
18. Costa Rica and adjoining parts of Panama.
19. Panama Canal Zone and adjoining parts of Panama.
20. Sinu region, Colombia.
21. Coastal region, Colombia.
22. El Banco, Colombia.
23. Atrato Valley, Colombia.
24. Maracaibo Basin, Venezuela.
25. Falcon, Venezuela.
26. Margarita.
27. Trinidad.
28. Tobago.
29. Darien, Panama.
30. Veraguas, Los Santos, and Herrera Provinces, Panama.
31. Chiriqui Province, Panama.
32. Puntarenas and interior of Costa Rica.
33. Nicaragua.

the others put together—two lower, three middle, and one upper. So far as the mollusks are concerned, the beds that are called Miocene carry larger faunas than any of the others. Incomplete collections from the Cercado, Gurabo, Gatun, and Bowden formations probably would look so much alike that all would be lumped in one zone, whereas three actually are recognized. Therefore, it is clear that finer age distinctions are being made in the Miocene part of the section than in any other part. Still the possibility that Oligocene and Pliocene beds are being placed in the Miocene needs consideration. It is more probable, however, that the Cerros de Sal formation and the Springvale beds are Pliocene than that the Anguilla formation is Oligocene, and perhaps the Bowden formation and the upper zone of the Gatun formation should be placed in the upper Miocene.

The Bowden mollusks naturally are most similar to those found in Miocene deposits elsewhere in tropical America, which embraces southern Mexico, Central America, the West Indies, and northern South America.

The following discussion is planned to summarize the published information on the Miocene mollusks of this region and to put on record unpublished data based on collections in the United States National Museum. The localities that are considered are shown diagrammatically in fig. 2.

The table facing page 41 shows at a glance the relative age of these Miocene deposits, as here presented.

LITERATURE LIST FOR TROPICAL AMERICA

The following list covers reports on the Miocene mollusks of tropical America that were consulted in the preparation of this report. Abbreviated lists are given later for each group of localities that can be treated as a unit. Reports containing only lists of fossils are not included in this literature list, except for a few localities for which no other data are on record. The locality lists include not only reports that describe material from that locality, but also reports dealing primarily with other localities, in which species may be incidentally described or figured.

Literature list for Miocene mollusks from tropical America

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- "1852." ORBIGNY, A. D'. Paléontologie de l'île de Cuba. In Ramon de la Sagra, Histoire physique, politique et naturelle de l'île de Cuba, 64 pp., 8 quarto pls.
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1866. GUPPY, R. J. LECHMERE. On the Tertiary Mollusca of Jamaica. Quart. Jour. Geol. Soc. London, vol. 22, pp. 281-295, pls. 16-18.
- 1866a. GUPPY, R. J. LECHMERE. On the relations of the Tertiary formations of the West Indies. Quart. Jour. Geol. Soc. London, vol. 22, pp. 570-590, pl. 26, 3 figs.
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and descriptions of some new fossils from the Caribbean Miocene. *Geol. Mag.*, vol. 4, pp. 496-501, 6 figs.

1870. NELSON, EDWARD T. On the molluscan fauna of the later Tertiary of Peru. *Trans. Connecticut Acad. Arts Sci.*, vol. 2, pp. 186-206, pls. 6-7.
1873. GABB, WILLIAM M. Descriptions of some new genera of Mollusca. *Proc. Acad. Nat. Sci. Philadelphia*, 1872, pp. 270-274, pls. 9-11.
- 1873a. GABB, WILLIAM M. On the topography and geology of Santo Domingo. *Trans. Am. Philosophical Soc.*, n. s., vol. 15, pp. 49-259, 2 maps.
1873. GUPPY, R. J. LECHMERE. On some new Tertiary fossils from Jamaica. *Proc. Sci. Assoc. Trinidad*, vol. 2, No. 2, pt. 10, pp. 72-88, pls. 1-2. Reprint in *Bull. Am. Paleontology*, vol. 8, pp. 204-220, 1921.
- 1873a. GUPPY, R. J. LECHMERE. On some new species of bivalve Mollusca found at Cumana, Venezuela. *Proc. Sci. Assoc. Trinidad*, vol. 2, pp. 90-92, pl. 3. Reprint in *Bull. Am. Paleontology*, vol. 8, pp. 221-223, 1921.
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1906. BÖSE, EMILIO. Sobre algunas faunas terciarias de México. Inst. Geol. México, Bol. 22, 96 pp., 12 pls.
1906. JOUKOWSKY, E., and M. CLERC. Sur quelques affleurements nouveaux de roches tertiaires dans l'isthme de Panama. Mém. Soc. Phys. Hist. Nat. Geneva, vol. 35, pt. 2, pp. 155-178, pls. 6-7, 5 figs.
1907. SMITH, BURNETT. A contribution to the morphology of *Pyrula*. Proc. Acad. Nat. Sci. Philadelphia, vol. 59, pp. 208-219, pl. 17, 2 figs.
1908. GUPPY, R. J. LECHMERE. On some fossil shells from Compara Road, Trinidad. Bull. Misc. Information Trinidad Botanical Dept., July 1908, pp. 114-115. Reprint in Bull. Am. Paleontology, vol. 8, pp. 288-289, 1921.
1909. TOULA, F. Eine jungtertiäre Fauna von Gatun am Panama-Kanal. Jahrb. K.-k. geol. Reichsanstalt, vol. 58, pp. 673-760, pls. 25-28, 15 figs.
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1910. ENGERRAND, JORGE, and FERNANDO URBINA. Primera nota acerca de la fauna miocénica de Zuluzum (Chiapas). Bol. Soc. geol. Mexicana, vol. 6, pt. 2, pp. 119-140, pls. 58-60.
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- 1911a. TOULA, F. Die jungtertiäre Fauna von Gatun am Panama-Kanal, II. Teil. Jahrb. K.-k. geol. Reichsanstalt, vol. 61, pp. 487-530, pls. 30-31.
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1912. MAURY, CARLOTTA J. A contribution to the paleontology of Trinidad. Jour. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 15, pp. 25-112, pls. 5-13.
1913. BROWN, AMOS P., and HENRY A. PILSBRY. Fauna of the Gatun formation, Isthmus of Panama, II. Proc. Acad. Nat. Sci. Philadelphia, vol. 64, pp. 500-519, pls. 22-26, 5 figs.
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1917. MAURY, CARLOTTA JOAQUINA. Santo Domingo type sections and fossils. *Bull. Am. Paleontology*, vol. 5, pp. 165-459, pls. 28-67.
1917. SHELDON, PEARL G. Atlantic slope Arcas. *Palaeontographica Americana*, vol. 1, No. 1, pp. 1-101, pls. 1-16.
1917. PILSBRY, HENRY A., and C. W. JOHNSON. New Mollusca of the Santo Domingan Oligocene. *Proc. Acad. Nat. Sci. Philadelphia*, vol. 69, pp. 150-202.
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1919. VAN WINKLE, KATHERINE. Remarks on some new species from Trinidad. *Bull. Am. Paleontology*, vol. 8, pp. 19-27, pl. 3.
1920. MAURY, CARLOTTA J. Tertiary Mollusca from Porto Rico. *New York Acad. Sci. Scientific Survey Porto Rico and Virgin Islands*, vol. 3, pt. 1, pp. 1-77, pls. 1-9.
1920. SANCHEZ ROIG, MARIO. Escualidos del Mioceno y Plioceno de la Habana, Cuba, Dirección Montes y Minas, *Bol. Minas* 6, pp. 1-16, 27 figs.
Four species of mollusks are listed and figured.
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1921. COOKE, C. WYTHE. New names for West Indian Tertiary Peetens. *Nautilus*, vol. 34, p. 137.
- 1921a. COOKE, C. WYTHE. *Orthaulax*, a Tertiary guide fossil. *U. S. Geol. Survey Prof. Paper* 129, pp. 23-37, pls. 2-5.
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1922. BERRY, EDWARD W. An American Spirulirostra. *Am. Jour. Sci.*, ser. 5, vol. 3, pp. 327-334, 5 figs.
1922. PILSBRY, HENRY A. Revision of W. M. Gabb's Tertiary Mollusca of Santo Domingo. *Proc. Acad. Nat. Sci. Philadelphia*, vol. 73, pp. 305-435, pls. 16-47, 48 figs.
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1922. WOODS, HENRY. Mollusca from the Eocene and Miocene deposits of Peru. In T. O. Bosworth, *Geology of the Tertiary and Quaternary periods in the northwest part of Peru*, pp. 51-111, 20 pls.
1922. SPIEKER, EDMUND M. The paleontology of the Zorritos formation of the north Peruvian oil fields. *Johns Hopkins Univ. Studies in Geology*, No. 3, 196 pp., 10 pls.

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1923. WOODRING, WENDELL P. Tertiary mollusks of the genus *Orthaulax* from the Republic of Haiti, Porto Rico, and Cuba. Proc. U. S. Nat. Mus., vol. 64, art. 1, 12 pp., 2 pls.
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- 1925a. MAURY, CARLOTTA J. Fosseis terciarios do Brasil com descripção de novas formas cretaceas. Brasil Serv. Geol. Mineral. Mon., vol. 4, 711 pp., 24 pls., map.
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1927. ANDERSON, FRANK M. The marine Miocene deposits of North Colombia. *Proc. California Acad. Sci.*, ser. 4, vol. 16, No. 3, pp. 87-95, pls. 2-3.
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¹ This publication was received too late to be considered in the matter dealing with the descriptions of the Bowden gastropods. It should be pointed out that "*Venericardia*" *bowdenensis*, described as a new Bowden species, is a synonym of *Cardita scabricostata* Guppy 1866.

CARIBBEAN REGION

WEST INDIES

DOMINICAN REPUBLIC

The literature list for Miocene mollusks from the Dominican Republic is as follows:

Literature list, Dominican Republic

Sowerby 1850	Cossmann 1913
Guppy 1866a	Sheldon 1917
Guppy 1867	Pilsbry and Brown 1917
Gabb 1873	Maury 1917
Gabb 1873a	Pilsbry and Johnson 1917
Guppy 1876	Maury 1920
Gabb 1881	Cooke 1921a
Gabb 1881a	Van Winkle 1921
Dall 1890-1903	Pilsbry 1922
Dall 1896	Olsson 1922
Guppy and Dall 1896	Hanna 1924
Pilsbry and Sharp 1897-98	Maury 1925
Pilsbry and Sharp 1898	Woodring 1925
Grabau 1904	Woodring 1925a
Maury 1910	Maury 1925a
Brown and Pilsbry 1911	Hodson 1926
Brown and Pilsbry 1913	Palmer 1927

The most complete Miocene section in the West Indies is found in the northern part of the Dominican Republic along northward-flowing streams that enter the Cibao Valley as tributaries of Rio Yaque del Norte and Rio Yuna. This section, as described by Cooke (Mem. Geol. Survey Dominican Republic, vol. 1, pp. 63-75, 1921), in descending order is as follows:

Miocene section in northern part of Dominican Republic

Time subdivision	Formation
Middle Miocene	Mao clay Mao Adentro limestone Gurabo formation Cercado formation Bulla conglomerate
Lower Miocene	Baitoa formation Cevicos limestone

Of these deposits those from the Bulla conglomerate to Mao clay, inclusive, are known from field studies to lie one on top of the other. The Baitoa formation on stratigraphic grounds clearly is older than the Cercado formation, but the boundary between them was not seen. All these beds crop out on tributaries of Rio Yaque del Norte, whereas the Cevicos limestone crops out farther east in the drainage basin of Rio Yuna.

Only a few fossils were collected from the Cevicos limestone, but those that were collected, particularly the echinoids, show that it is of the same age as the Anguilla formation of the island of Anguilla, which is now regarded as representing the lowest Miocene zone in this region. *Orthaulax aguadillensis* Maury is found in the Cevicos limestone and also in the next younger zone. This genus disappeared before the beginning of Cercado time and has never been found in the Bowden formation nor in any beds that are considered of about the same age. Gabb apparently collected from the Cevicos limestone, as he records "*Lithophagus corrugatus* Phil." "found boring coral at Cevico" (Trans. Am. Philos. Soc., n. s., vol. 15, p. 253, 1873).

The Bulla conglomerate was supposed to be of about the same age as the Baitoa formation, but it probably represents the basal beds of the Cercado formation, for the conglomerate is gradually replaced by sandy beds, and Cercado fossils are found in these transition beds (U. S. G. S. station 8529).

The Baitoa, Cercado, and Gurabo formations are discussed in the following pages. The Mao Adentro limestone may be interpreted as representing patches of reef limestone in the upper part of the Gurabo formation. Like most reef limestones, it carries relatively few mollusks. The fossils of the Mao clay are negligible. Its mollusks are like those of the Gurabo formation, and so far as they are concerned both the Mao Adentro limestone and Mao clay could be regarded as parts of the Gurabo formation.

Almost all the mollusks described in the Dominican literature are from the Baitoa, Cercado, and Gurabo formations, and by this time most of the species are described, the largest reports being those by Gabb (1873), Maury (1917), and Pilsbry (1922). Pilsbry's revision of the Gabb collection is very valuable, for in it the unfigured and unlocated species described by Gabb are figured and Gabb's many errors are corrected. By utilizing the stratigraphically located material collected by the Maury and United States Geological Survey parties it is possible to determine the age of most of Gabb's species and also those described by Sowerby and Guppy, but Gabb collected many species that no one else has found. The names in the lists that Mansfield and I published (Mem. Geol. Survey Dominican Republic, vol. 1, pp. 113-145, 1921), and for which I must take full responsibility, are not to be taken seriously. Many of the so-called new species in these

lists turn out to be species described by Gabb or by Pilsbry and Johnson, others are Recent species, and others are described fossil species that have a greater stratigraphic range than was supposed. Also the generic nomenclature is unreliable. The preliminary studies on which these lists are based were made for stratigraphic purposes and they served that end. About 900 specific names, based on descriptions, not lists, are already on record for mollusks from these deposits, but many of these names are synonyms. Maury renamed a number of Gabb's species, and Pilsbry and Johnson renamed some of Maury's species, and several of Sowerby's species, the first to be described from the Dominican Republic, have received other names. Though most of the species are described, a great deal of work remains to be done in straightening out these synonyms. During the preparation of this report the extensive collections made by the United States Geological Survey party were constantly consulted and the comparison between the Bowden and the Dominican mollusks has the advantage of uniform treatment based on specimens.

About 60 species were collected from the Baitoa formation. The most characteristic, none of which has been found in the Cercado or Gurabo formations, nor in the Bowden formation, are as follows:

Characteristic mollusks of Baitoa formation

<i>Conus williamgabbi</i> Maury	"Phos" <i>costatus</i> Gabb
<i>Xancus rex</i> Pilsbry and Johnson	<i>Cymia henekeni</i> Maury
<i>Fasciolaria kempi</i> (Maury)	<i>Orthaulax inornatus</i> Gabb
"Phos" <i>semicostatus</i> Gabb	<i>Anadara hispaniolana</i> (Maury)

Gabb did not believe in leaving records of localities, but it is clear that he and also Colonel Heneken, who collected the material Sowerby and Guppy described, collected from the Baitoa formation. In all probability many of Gabb's species not found by later collectors are from these beds, and he may have found a better locality than the type locality on Rio Yaque del Norte at Baitoa, for large numbers of the characteristic Baitoa species are in the Gabb collection. *Anadara patricia* (Sowerby), also known as "*Scapharca (Argina)*" *tolepis* Dall and "*Scapharca*" *arthurpennelli* Maury, which is very abundant in the Cercado formation, and other species are found in both the Baitoa and Cercado formations. *Conus aemulator* Brown and Pilsbry, of which *C. veatchi* Olsson is a synonym, and *Conus imitator* Brown and Pilsbry are found in the Baitoa, Cercado, and Gurabo formations, as well as in the Gatun formation of the Panama Canal Zone. *Galeodes consors* (Sowerby) and *Pachycrommium guppyi* (Gabb) also are Baitoa, Cercado, and Gurabo species. Other Baitoa species extend into the Gurabo formation and more are similar to Cercado and Gurabo species. *Pachycrommium guppyi* and two doubtfully identified species, *Conus proteus* Hwass and *Distorsio decussatus simillimus* (Sowerby), the

former a Recent species, seem to be the only Bowden species that are known from the Baitoa formation. The fauna of the Baitoa formation is clearly recognizable and it is considered of lower Miocene age, the upper one of the two lower Miocene zones now recognized in this region.

The Cercado formation carries about 500 species of mollusks, more than any other Dominican formation. It corresponds to Maury's "*Aphera islacolonis* formation." The overlying Gurabo formation, Maury's "*Sconsia laevigata* formation," carries about 400 species. The mollusks of these two formations are so similar that it is best to consider them together. Collections of fair size from these two formations generally can readily be discriminated, but many of the species are found in both. Transitional beds carry a Cercado fauna modified by the first appearance of Gurabo species (see Vaughan and Woodring, Mem. Geol. Survey Dominican Republic, vol. 1, pp. 97-98, 1921), indicating that if detailed field work were attempted it would be difficult, or perhaps impossible, to draw a boundary between them. The following are among the easily recognized Cercado species that were not found in the Gurabo formation:

Characteristic mollusks of Cercado formation

"Cythara" polygona Gabb	"Phos" gabbii Dall
Conus furvoides Gabb	Anadara patricia (Sowerby)
Conus cercadensis Maury	Anadara coreupidonis (Maury)
Aphera islacolonis (Maury)	Cardium dominicanum Dall
Persicula cercadensis (Maury)	Corbula viminea Guppy

The list of characteristic Gurabo species that were not found in the Cercado formation is larger, including the following:

Characteristic mollusks of Gurabo formation

Terebra haitensis Dall ("T. sulcifera Sowerby" of authors)	Cancellaria guppyi Gabb
"Clavatula" labiata Gabb	Marginella coniformis Sowerby
"Drillia" squamosa Gabb	Lyria pulchella (Sowerby) ¹
Clathrodrillia venusta (Sowerby)	Tritiaria elegans (Guppy)
Scobinella magnifica (Gabb)	Metutella venusta (Sowerby)
Conus haytensis Sowerby ¹	Distorsio decussatus similimus (Sowerby)
Conus recognitus Guppy (C. yaquensis Gabb)	Sconsia laevigata (Sowerby)
Conus stenostoma Sowerby	Morum domingense (Sowerby)
Conus planiliratus Sowerby	Crepidacella melanoides (Gabb)
Conus multiliratus gaza Johnson and Pilsbry	Ostrea haitensis Sowerby
Conus catenatus Sowerby	Chlamys thetidis (Sowerby) ("Pecten" eugrammatus Dall)
Conus consobrinus Sowerby	Antigona blandiana (Guppy)

¹ Recorded by Maury from the Cercado formation.

Some of these species, however, are found in the "modified Cercado fauna." Maury's guide fossils—*Aphera islacolonis* for the Cercado formation and *Sconsia laevigata* for the Gurabo formation—were well chosen, for collections so far made have verified their range.

It would not be safe to assume that the difference between the Cercado and Gurabo faunas is due entirely to difference in age. Some of the genera and species conclusively show that it is not. Many of the characteristic Gurabo species belong to genera—"Clavatula," "Drillia" (*squamosa* Gabb), *Scobinella*, *Lyria*, *Metutella*, *Distorsio*, *Sconsia*, *Morum*, and *Crepitacella*—that are not represented at all in the Cercado formation, though it is known that they were living elsewhere during Cercado time or during even earlier periods. In like manner some of the characteristic Cercado species represent genera—*Aphera* and *Bothrocorbula*—not found in the Gurabo formation, though again they are known to have been living then elsewhere. *Distorsio decussatus simillimus* (Sowerby) is abundant in the Gurabo formation, but it is not found in the Cercado formation, though it probably is represented in the older Baitoa formation. *Murex recurvirostris* Broderip, *Trivia globosa* ("Gray") Sowerby, *Barbatia domingensis* Lamarek, *Diplodonta gabbi* Dall, and *Strigilla pisi-formis* (Linné) are Recent species that occur in the Cercado formation, but not in the younger Gurabo formation. Assuming that the collections are adequate, such features show that at least some of the difference is due to some kind of ecologic control. Without knowing more about the distribution both in space and time of these and other genera involved and their ecologic significance it is impossible to determine their full significance. Perhaps one generalization is worth recording. The Cercado formation carries a large number of small species and genera not found in the Gurabo formation, and the proportion of large thick-shelled species is far greater in the Gurabo formation, though the material on which this comparison is based was collected in bulk—the only method that insures a representation of small shells—by the same collectors. Perhaps the Cercado formation, at least so far as it is known, was deposited in quiet protected water, whereas the Gurabo formation at most of the localities explored was deposited in places exposed to heavy surf. At one locality where a collection was made (U. S. G. S. station 8702) the Gurabo formation was laid down in relatively deep quiet water, and at this locality virtually all the thick-shelled species are absent.

I have several times gone on record as considering the Cercado formation of lower Miocene age, but I now think that it should be placed with the Gurabo formation in the middle Miocene, these two formations representing different zones in the middle Miocene. Either the Cercado formation overlaps the Baitoa formation along the greater part of the southern edge of the Cibao Valley, or the Baitoa formation

Bowden species found in Cercado and Gurabo formations¹

SPECIES	Cercado forma- tion	"Modi- fied" Cercado fauna	Gurabo forma- tion	Deeper water facies of Gurabo forma- tion
Gastropods:				
<i>Cavolina telemus</i> (Linné).....			?	
<i>Diacria bisulcata</i> Gabb.....	×			
<i>Acteon riomaensis</i> Maury.....	×	×		
<i>Volvula oxytata</i> Bush.....	×	×	×	×
<i>Volvula ornata</i> Johnson and Pilsbry.....			×	
<i>Cylichna aula</i> Woodring.....				×
<i>Ringicula tridentata</i> Guppy.....				×
<i>Terebra eluthera</i> Woodring.....			×	
<i>Leptadrillia parkeri</i> (Gabb).....			×	
<i>Bactrocythara obtusa</i> (Guppy).....	×			
<i>Euclathurella vendryesiana</i> (Dall).....			×	
<i>Scobinella magnifica</i> (Gabb).....			×	
<i>Conus proteus</i> Hwass.....	×		×	
<i>Conus stenostoma</i> Sowerby.....			×	
<i>Conus planiliratus</i> Sowerby.....		×	×	×
<i>Conus multiliratus</i> gaza Pilsbry and Johnson..		×	×	
<i>Conus catenatus</i> Sowerby.....			×	
<i>Conus consobrinus</i> Sowerby.....		×	×	?
<i>Oliva plicata</i> Guppy.....	×	?	×	?
<i>Marginella coniformis</i> Sowerby.....			×	×
<i>Tritiaria elegans</i> (Guppy).....			×	×
<i>Nassarius cercadensis</i> (Maury).....	×	×	×	×
<i>Nassarius gurabensis</i> (Maury).....			×	
<i>Mitrella lepta</i> Woodring.....	×		×	
<i>Strombina caribaea</i> Gabb.....			×	×
<i>Murex recurvirostris</i> Broderip.....	×	×		
<i>Coralliophila miocenica</i> (Guppy).....			×	
<i>Distorsio decussatus</i> similimus (Sowerby)....		×	×	
<i>Cassis sulcifera</i> Sowerby.....	×	×	×	×
<i>Semicassis reclusa</i> (Guppy).....	×	×	×	
<i>Malea camura</i> Guppy.....	×		×	?
<i>Ficus pilsbryi</i> (B. Smith).....	?			
<i>Cypraea isabella patrespatriae</i> Maury.....			×	
<i>Trivia globosa</i> ("Gray") Sowerby.....	×			
<i>Strombus pugiloides</i> Guppy.....			?	
<i>Strombus bifrons</i> Sowerby.....			×	
<i>Alabina curta</i> Woodring.....	×		×	
<i>Alaba turrita</i> Guppy.....			×	
<i>Modulus modulus</i> basileus (Guppy).....			×	
<i>Vermicularia spirata</i> (Philippi).....	×	×	×	×
<i>Lemintina papulosa</i> (Guppy).....	×		×	×
<i>Architectonica nobilis</i> quadriseriata (Sowerby)..	×	×	×	
<i>Architectonica euprepes</i> Woodring.....	×		×	×
<i>Rissoina guppyi</i> Cossmann.....	×		×	
<i>Rissoina pyrgus</i> Woodring.....			×	
<i>Rissoina browniana</i> d'Orbigny.....	×	×	×	×
<i>Capulus lius</i> Woodring.....			×	
<i>Xenophora delecta</i> (Guppy).....			×	

¹ In this list and in other similar lists turrids of the *Polystira albidus* group and Naticas of the *canrena* group are omitted.

Bowden species found in Cercado and Gurabo formations—Continued

SPECIES	Cercado forma- tion	"Modi- fied" Cercado fauna	Gurabo forma- tion	Deeper water facies of Gurabo forma- tion
<i>Stigmaulax vererugosum</i> Cossmann.....	×	×	×	×
<i>Tectonatica pusilla</i> (Say).....	×	×	×	×
<i>Polinices brunnea subclausa</i> (Sowerby).....	×		×	×
<i>Sigatica semisulcata bathyora</i> Woodring.....	×			
<i>Sinum gatunense</i> (Toula).....	×			
<i>Pachycrommium guppyi</i> (Gabb).....	×	×	×	×
<i>Epitonium gabbi</i> de Boury.....	×			
<i>Turbo dominicensis</i> Gabb.....	×		×	?
<i>Smaragdia viridis viridimaris</i> (Maury).....	×	×	×	×
<i>Microgaza cossmanni</i> Woodring.....			×	
<i>Diodora alternata henekeni</i> (Maury).....	×			
Scaphopods:				
<i>Dentalium cossmannianum</i> Pilsbry and Sharp..			×	
<i>Dentalium glaucoterrarum</i> Maury.....	×		×	×
<i>Dentalium dissimile dissimile</i> Guppy.....	×	×	×	×
<i>Dentalium dissimile ponderosum</i> Gabb.....	×		×	
<i>Dentalium haytense</i> Gabb.....	×	×	×	
" <i>Dentalium</i> " <i>rudis</i> Gabb ¹			×	
Pelecypods:				
<i>Yoldia ovalis</i> Gabb.....			×	
" <i>Arca</i> " <i>occidentalis</i> Philippi.....			×	
<i>Barbatia domingensis</i> (Lamarck).....	×			
<i>Anadara inaequilateralis</i> (Guppy).....	×			
<i>Pteria inornata</i> Gabb.....	×			
<i>Chlamys vaginulus</i> (Dall).....			×	
<i>Amusium papyraceum</i> (Gabb) ?.....	×	×	×	?
<i>Spondylus bostrychites</i> Guppy.....		×	×	?
<i>Limea solida</i> Dall.....			×	
<i>Placunanomia lithobleta</i> Dall.....			×	
<i>Anomia indecisa</i> Dall.....	×	×	?	
<i>Chama involuta</i> Guppy.....	×		×	
<i>Phacoides actinus</i> Dall.....	?			
<i>Diplodonta gabbi</i> Dall.....	×			
<i>Cardium medium</i> Linné.....			×	
<i>Cardium haitense haitense</i> Sowerby.....	×	×	×	×
<i>Cardium haitense cercadium</i> Maury.....	×	×		
<i>Cardium serratum</i> Linné.....	×		×	
<i>Pitar carbaceus</i> (Guppy).....		×		
" <i>Pitar</i> " <i>planivietus</i> (Guppy).....	×	×	×	
<i>Antigona blandiana</i> (Guppy).....			×	×
<i>Chione sawkinsi</i> Woodring.....	×			
<i>Chione woodwardi</i> (Guppy).....	×	×		
<i>Chione hendersonii</i> Dall.....	×	×	×	?
<i>Tellina healeyi</i> Woodring.....	×	×		
<i>Strigilla pisiformis</i> (Linné).....	×	×		
<i>Psamosolen sanctidominici</i> Maury.....	×		×	
<i>Corbula viminea</i> Guppy.....	×	×		

¹ This species, which is a worm tube, was discovered in a Bowden collection after Publication 366 was issued.

was eroded in places before it was laid down, for it is reasonably certain that the Cercado formation west of the type locality of the Baitoa formation rests directly on the metamorphic rocks. There also is a more pronounced faunal break between the Baitoa and Cercado than between the Cercado and Gurabo. Therefore, on both stratigraphic and faunal grounds the interval between the Baitoa and Cercado formations is a convenient place for the boundary between lower and middle Miocene. Whether this boundary corresponds to the division between lower and middle Miocene in the European section has not been determined and perhaps can never be determined.

The Bowden fossils are more similar to those of the Cercado and Gurabo formations than to those of any other Miocene deposits. The Bowden species listed on pages 54–55 are found in the Cercado and Gurabo formations. Others probably will be added when the Dominican collections are fully studied.

In addition, *Typhis alatus obesus* Gabb, *Sinum excentricum* (Guppy), *Episcynia naso* (Pilsbry and Johnson), and *Cadulus depressicollis* Pilsbry and Sharp are represented in stratigraphically unlocated collections from the Dominican Republic.

Of the 93 species in the preceding list, 88 are definitely determined, and of these 57 are found in the Cercado formation, 68 in the Gurabo formation, and 37 in both. For a fair comparison with the Cercado formation six of the 57 species should be dropped, for they are found in the "modified Cercado fauna," and not in the normal Cercado fauna. A comparison of similar instead of identical species would give comparable results. These similar species are noted in the descriptions. On the face of this list the Bowden fossils are similar to those of both the Cercado and Gurabo formations, but more closely resemble those of the Gurabo formation. However crude strictly numerical comparisons of fossils may be with their varying and indeterminable standards, this list seems to express in a general way the relations of the Bowden and Dominican faunas. There is no reason, however, to believe with Maury (Bull. Am. Paleontology, vol. 5, p. 433, table at end, 1917) that the Bowden fauna is "seemingly a mixed fauna representing these two formations." This quotation from Maury's correlation table implies a stratigraphic mixture, but the discussion on page 433 could be interpreted to mean both stratigraphic and ecologic mixing. The principal reason why the Bowden fauna resembles both rather than showing a clean-cut resemblance to one is because it is considerably larger than either. It represents a greater ecologic range and gives a more complete representation of the total number of shell-bearing mollusks then living. It embraces genera that are found only in the Cercado formation, and genera that are found only in the Gurabo formation, and also many genera that are found in neither. So far as Maury's guide fossils are concerned, the Bowden formation

carries no species of *Aphera*, but it carries a *Sconsia*, not, however, the Gurabo species. No particular age significance can be attached to either of these genera. *Aphera* is found in the Gatun formation of the Panama Canal Zone and also in the Miocene beds at Port Limon, Costa Rica, both of which certainly are younger than the Cercado formation. The lower Miocene beds of Costa Rica carry a *Sconsia* and for that matter the genus is recorded in deposits as old as the upper Oligocene Byram marl. Of the six Bowden species of *Conus* in the Dominican Republic, all are Gurabo species, whereas only one, a Recent species, is a Cercado species, though three others are found in the "modified Cercado fauna." *Marginella coniformis* Sowerby, *Tritiaria elegans* (Guppy), and *Strombus bifrons* Sowerby are abundant in both the Bowden and Gurabo formations, but they have not been collected from the Cercado formation. On the other hand, *Murex recurvirostris* Broderip (also known as *M. messorius* Sowerby) is found in the Bowden and Cercado formations, but a similar species, *M. domingensis* Sowerby, occurs in the Gurabo formation. *Corbula viminea* Guppy is another Bowden and Cercado species not found in the Gurabo formation. *Cylichna aula* Woodring and *Ringicula tridentata* Guppy were collected only from the deep-water Gurabo locality, which gives a clue to the significance of ecologic factors. It is not yet possible to make comparisons based on percentage of Recent species. About 11 per cent of the Bowden species occur in the Gurabo formation. This is not a very high percentage for faunas of approximately the same age. The percentage of Gurabo species found at Bowden will run higher. In comparing the Bowden and Gurabo faunas, it should be remembered that these localities are about 400 miles apart and in slightly different regions, the one on the outer or Atlantic edge of the West Indies and the other on the inner or Caribbean edge. The Bowden formation lacks some of the conspicuous Gurabo genera—"Clavatula," "Drillia" (*squamosa* Gabb), *Lyria*, *Morum*, *Pustularia*, and *Turgurium*—and it carries no cones like *C. haytensis* Sowerby, and no Cancellarias like *C. epistomifera* Guppy. It is not now possible to determine how much of this difference is due to geographic and facies factors and how much is due to difference in age.

It is concluded that the Bowden fossils are more like those of the Gurabo formation than like any other Dominican fossils. In view of the closer similarity of the Gurabo and Gatun faunas, which is discussed later, and in view of the presence in the Bowden formation of some Recent species not found in either the Gurabo or Gatun formations, the Bowden fossils are regarded as representing a younger horizon.

Miocene fossils also have been collected in the southern part of the Dominican Republic, but only a few of them have been described. *Orthaulax aguadillensis* Maury (see Cooke 1925a), *Turritella calostemma*

Pilsbry and Brown (1917), and *Dosinia azuana* Pilsbry and Johnson (1917; Pilsbry 1922) seem to be the only species so far described from the region about Azua and the valley of Rio Yaque del Sur. The collections made by the United States Geological Survey party are from the valley of Rio Yaque del Sur. I now doubt whether Vaughan and I were justified in accusing the collectors of mixing more than one horizon (Mem. Geol. Survey Dominican Republic, vol. 1, pp. 102-103, 1921). We probably were looking for too close a similarity with the Miocene fossils of the northern part of the country. These Miocene beds of the Yaque del Sur Valley extend westward into the San Juan Valley (Condit and Ross, Mem. Geol. Survey Dominican Republic, vol. 1, p. 211, 1921), and it is only a matter of time until their relations to the Thomonde and Las Cahobas formations of the Central Plain, the Haitian part of the San Juan Valley, are known. The Thomonde formation carries *Orthaulax aguadillensis* Maury, and so do some of these beds. Otherwise, however, the fossils are not very similar, which is all the more perplexing in view of the marked similarity of the Thomonde fossils to those in the Baitoa formation on the north side of the island. The presence of a *Senilia* closely resembling the Recent Panamic *S. grandis* (Broderip and Sowerby) was particularly misleading when these Dominican collections were first examined. This large "*Arca*," which generally goes under the name of "*Arca patricia* Sowerby," was not found in the northern part of the country by the United States Geological Survey party, and the Maury party collected it only high in the section. It turns out that this fossil *Senilia*, and also other species from tropical America ("*Arca*" *chiriquiensis* Gabb, "*Arca*" *chiriquiensis websteri* Pilsbry, and "*Arca*" *dolaticosta* Pilsbry and Johnson), not only tolerated, but generally even preferred, brackish water, which probably accounts for its apparent greatly restricted range in the Cibao Valley. These fossils from the Yaque del Sur Valley are not at all comparable with those from Bowden.

The Cerros de Sal formation, which crops out in the Enriquillo Basin, is considered younger than the beds just described. It was originally placed in the upper Miocene (Mem. Geol. Survey Dominican Republic, vol. 1, pp. 75, 103, 201, 214-215, 1921), and there seems to be no reason to change this assignment, though it probably is not much younger than the Bowden formation. Aside from the Recent species "*Arca*" *occidentalis* Philippi and *Cardium medium* Linné, both of which are Bowden and Cerros de Sal species, a number of other Cerros de Sal species are very similar to Bowden species (a *Lemintina* like *L. papulosa* (Guppy), a *Turritella* that may be *T. guppyi* Cossmann and an *Anadara* like *A. halidonata* (Dall)). A Cerros de Sal *Solenosteira* probably is *S. medioamericana* Olsson. This formation carries a representative of the *grandis*-like *Senilia*. According to

specimens in the collections of the United States National Museum the same beds are represented on an "island in Lake Henriquillo near Neyba," perhaps Isla de Cabritos. This island is the type locality of "*Pyrasisinus* ?" *haitensis* Dall and *Phacoides domingensis* Dall, both of which are found in the Cerros de Sal formation. According to other specimens, the Quaternary marine beds of the Enriquillo Basin also crop out on this island.

REPUBLIC OF HAITI

Literature on Miocene mollusks from the Republic of Haiti is as follows:

Literature list, Republic of Haiti

Pilsbry 1910	Pilsbry 1922
Sheldon 1917	Woodring 1923
Pilsbry and Brown 1917	Woodring and Mansfield 1924
Pilsbry and Johnson 1917	

This list is very short compared with the one for the Dominican Republic and accounts for only 17 species, aside from those only given in lists.

The largest number of mollusks are found in the Central Plain in the Thomonde formation and Maissade tongue, and in the overlying Las Cahobas formation. These deposits are fully described in the report on the geology of the Republic of Haiti. A few of the characteristic fossils are figured and lists are given (Woodring and Mansfield, *Geology of the Republic of Haiti*, pp. 165-205, pls. 15-16, 1924). These lists also are not to be taken too seriously, although they probably are more reliable than those for the Dominican Republic, except in the matter of generic nomenclature. The Thomonde formation carries *Xancus rex* Pilsbry and Johnson, "*Phos*" *semicostatus* Gabb, "*Phos*" *costatus* Gabb, and *Cymia henekeni* Maury, all of which have already been listed as characteristic species of the Baitoa formation of the Dominican Republic. It also carries other Baitoa species and *Orthaulax aguadillensis* Maury, which is like the Baitoa *O. inornatus* Gabb. It would not be surprising to discover that *Galeodes orthacanthus* (Pilsbry and Johnson), *Potamides dentilabris* (Gabb), and *Hemisinus truncatus* (Gabb), which were collected by Gabb, but by no one else in the Dominican Republic, and which are found in the Thomonde formation, will be discovered in the Baitoa formation, though all are facies (brackish- and fresh-water) fossils and may have a considerable stratigraphic range. It should be pointed out that *Conus aemulator* Brown and Pilsbry is an older name for the cone figured in the Haitian report as "*C. veatchi* Olsson." The correlation of the Thomonde formation with the lower Miocene Baitoa formation is as definite as any correlation in this region. Inasmuch as about

350 species of mollusks were collected from the Thomonde formation, whereas only 60 species have so far been collected from the Baitoa formation, it is taken as the type formation of this zone. It is the largest unworked Miocene fauna in the West Indian region, but many of the species will turn out to be Dominican species. At this time it is impracticable to list the Bowden species that are found in the Thomonde formation, but it is quite unnecessary to compare in any detail the fossils of the two formations, even though a number of species occur in both.

According to its position overlying the Thomonde formation, the fossils of the Las Cahobas formation should be more like those from Bowden, but they are not, principally because only about 50 species were collected from the Las Cahobas formation, and they came from oyster and coral reefs or from muds deposited near the mouths of rivers that contributed a considerable number of brackish- or fresh-water species. Though their fossils are so different, the Las Cahobas formation is considered the equivalent of the Cercado formation, and, therefore, according to the scheme here used, falls in the lower part of the middle Miocene. There is no evidence for an overlap of the Las Cahobas formation, comparable to the overlap of the Cercado formation, unless some beds along the northwest side of the Central Plain referred to the Thomonde formation represent the Las Cahobas formation.

Other Miocene beds cropping out along the south edge of the Cul-de-Sac Plain near Port-au-Prince carry fossils that are more similar to those from Bowden (Geology of the Republic of Haiti, pp. 219-223, 1924). As only about 35 species are represented, and as many of them are poorly preserved, no detailed comparison with the Bowden fossils can be made. A badly worn *Murex* from these beds seems to be *M. pomum* Gmelin, a Recent species that is found in the Bowden formation, but not in older beds. It was stated in the Haitian report that these beds probably are not as young as the Cerros de Sal formation of the eastern end of the trough of which the Cul-de-Sac Plain is a part, but they may be of the same age. The collections are not large enough to settle this point and these beds are regarded as representing the upper part of the middle Miocene or the upper Miocene.

CUBA

The literature list for Cuba is as follows:

Literature list, Cuba

d'Orbigny "1852"	Cooke 1921
Dall 1890-1903	Cooke 1921a
de Boury 1912	Woodring 1923
Cooke 1919	Maury 1925
Sanchez Roig 1920	

Less is known about the Miocene mollusks of Cuba than of any other of the larger West Indian islands, partly because the Miocene beds seem to consist principally of limestones, out of which most of the mollusks, except the oysters and Pectens, come as unsatisfactory molds. Apparently the plates of d'Orbigny's report, which has for the most part been disregarded, were issued with the Spanish edition of de la Sagra's monograph on Cuba, but very few copies of the text were distributed. The copy of the text (in French) in the library of the Philadelphia Academy of Natural Sciences is the only one I know of in this country. Of the 38 species described by d'Orbigny 16 are recorded only from Guadeloupe and Marie Galante. According to d'Orbigny's statements the Cuban specimens were collected for the most part from the Quaternary coralliferous limestones, but the Miocene beds at Santiago and probably those near Havana also seem to be represented. Similar material and many of the species are in the collections of the United States National Museum.

The fossils described by Cooke from the Angela Elmira asphalt mine near Bejucal, south of Havana, consisting principally of fresh-water mollusks, probably are of Oligocene age rather than Miocene. The limestone at Consolación del Sur, Piñar del Rio Province, is lower Miocene and seems to represent the lower zone—that is, it is considered of the age of the Anguilla formation. Both *Orthaulax caepa* Cooke and *O. aguadillensis* Maury are recorded from this limestone, though the presence of two species of *Orthaulax* in the same bed needs verification.

Middle Miocene beds probably are widely distributed in Cuba, but there is nothing so far known that can be compared with the Bowden mollusks. The correlation of the marl at Matanzas and Baracao on the north coast, and of the La Cruz marl at Santiago on the south coast, with the Bowden formation rests on the corals (see Vaughan, U. S. Nat. Mus. Bull. 103, pp. 218–219, 1919; Mem. Geol. Survey Dominican Republic, vol. 1, p. 99, 1921). *Pecten barretti* Woodring, from Bowden, may be a synonym of *P. ventonensis* Cooke, from the La Cruz marl. *Ostrea haitensis* Sowerby is recorded from the La Cruz marl and also from Matanzas, as well as from a locality near Havana. In the northern part of the Dominican Republic this species is found in the Gurabo formation, but in the Republic of Haiti it occurs in the Las Cahobas formation and also in the younger beds near Port-au-Prince. "*Metis trinitaria* Dall" of the La Cruz marl should take the name of *Metis sagrae* (d'Orbigny) ("*Tellina*"). It also is found near Havana. Perhaps Dall's name need not be suppressed, however, for the type is from the Springvale beds of Trinidad and may represent a different species.

Cassia sulcifera Sowerby and *Malea camura* Guppy are two Bowden species that are represented by doubtful molds in the Province of Havana.

PORTO RICO, VIEQUES, AND MONA

Reports dealing with the Miocene mollusks of Porto Rico, Vieques, and Mona are as follows:

Literature list, Porto Rico, Vieques, and Mona

Maury 1920	Maury 1925
Hubbard 1921	Maury 1925a
Cooke 1921a	Palmer 1927

One of these reports (Hubbard 1921) contains the only records for Vieques, which lies east of Porto Rico, and also for Mona, the little island in the passage between Porto Rico and the island of Haiti.

The Miocene beds of Porto Rico, Vieques, and Mona are limestones and the mollusks that they carry are for the most part poor molds like those from Cuba. The youngest Tertiary beds in Porto Rico are the Quebradillas limestone and the Ponce limestone, which crop out on the north and south sides of the island, respectively. The Quebradillas limestone carries *Orthaulax aguadillensis* Maury (called *O. portoricensis* by Hubbard), "*Phos*" *costatus* Gabb, a *Xancus* like *X. rex* Pilsbry and Johnson, and other species that probably are the same as Baitoa and Thomonde species. The correlation of the Quebradillas limestone with the Baitoa and Thomonde formations seems reasonably certain. This zone is perhaps the most definite and most easily recognized Miocene zone in the West Indies. In the eastern part of Porto Rico the Quebradillas limestone overlaps the older Tertiary beds and finally rests directly on the basement Cretaceous rocks (Hubbard, New York Acad. Sci. Scientific Survey Porto Rico and Virgin Islands, vol. 2, pt. 1, p. 48, 1923). A number of Bowden species are recorded from the Quebradillas and Ponce limestones. Although some of them are above suspicion, so many are based on virtually indeterminable material that it is inadvisable to list them. *Cancellaria laevescens portoricana* Maury represents a small race of the Bowden *C. l. laevescens* Guppy. It also was collected by Gabb, but by no one else, in the Dominican Republic, and it seems safe to assume that he collected it from the Baitoa formation.

The Ponce limestone probably is the equivalent of the Quebradillas limestone, but it may be a little younger. *Orthaulax* is not recorded from it and it carries *Ostrea cahobasensis* Pilsbry and Brown, which in the Republic of Haiti is found in the Las Cahobas formation.

The Aguadilla limestone (Los Puertos and Cibao limestones of Hubbard) seems to fall in the lowest Miocene horizon. It furnished the type specimen of *Orthaulax aguadillensis* Maury. To review Maury's and Hubbard's discussions of the age of the Porto Rican Tertiary beds would require too much space (see especially Hubbard, Scientific Survey Porto Rico and Virgin Islands, vol. 2, pt. 1, pp. 53-75, 1923). Unfortunately their work is not very well coordinated.

Maury fails to give the horizon under the species described and the data for the locality numbers have not yet been published. Hubbard's conclusion that the Bowden formation is upper Oligocene is not to be considered seriously.

Hubbard records *Orthaulax aguadillensis* Maury ("*O. portoricensis* Hubbard") from a limestone on Vieques. The conclusion that this limestone is the same as the Quebradillas limestone seems fully justified. On Vieques it rests directly on the basement Cretaceous rocks (Hubbard, Scientific Survey Porto Rico and Virgin Islands, vol. 2, pt. 1, p. 48, 1923), just as in eastern Porto Rico the Quebradillas limestone overlaps the older Tertiary beds.

Hubbard (p. 144) considers that the limestone on Mona is of the same age as the Quebradillas and Ponce limestones, but only two poorly preserved species are recorded from this small island.

ST. CROIX

The literature list for St. Croix is as follows:

Literature list, St. Croix

Dall 1890-1903

Cooke 1919

Cooke 1921a

St. Croix is the only one of the islands between Vieques and the Anegada Passage that is known to have any Miocene beds, which again consist of limestone carrying *Orthaulax aguadillensis* Maury. It seems quite safe to correlate this *Orthaulax*-bearing limestone with the Quebradillas limestone, which is widespread and transgressive in Porto Rico and along the south edge of the Virgin Bank. St. Croix is the type locality of *Conus cruzianus* Dall, which seems to have been ignored. It probably was collected from the lower Miocene limestone.

LESSER ANTILLES

Anguilla, Guadeloupe and Marie Galante, and Martinique are the only Lesser Antillean islands that need to be considered. Literature lists are as follows:

Literature list, Lesser Antilles

ANGUILLA

Guppy 1866a

Guppy 1867

Guppy 1874

Dall 1890-1903

Cooke 1919

Cooke 1921

Cooke 1921a

Maury 1925

Palmer 1927

GUADELOUPE AND MARIE GALANTE

d'Orbigny "1852"

Dall 1890-1903

MARTINIQUE

Cossmann 1913

Pilsbry 1922

The Anguilla formation of the island of Anguilla was for many years called upper Oligocene, but it is now considered lower Miocene and has been taken by Vaughan as the type of the lowermost Miocene zone in the West Indian region. About 43 species of mollusks are recorded from the Anguilla formation, but only 27 of them are named. The presence of *Orthaulax*, *Ampullina*, and *Ampullinopsis* clearly shows that the Anguilla formation is older than the Bowden formation. "*Pecten (Aequipecten) thetidis* Sowerby" and *Spondylus* "*bostrychites* Guppy" are the only species that might be the same as Bowden ones, but it is not certain that they are. "*Scapharca (Scapharca)*" *anguillana* Cooke, based on float material, is very similar to *Senilia chiriquiensis* (Gabb). It may indicate younger beds or brackish-water beds in the Anguilla formation.

Most of the mollusks recorded by d'Orbigny from Guadeloupe and Marie Galante apparently were collected from Quaternary limestones, like most of the Cuban ones. The record of "*Natica*" *phasianelloides* d'Orbigny, which seems to be an *Ampullina*, and the less definite record of "*Tellina*" *sagrae* d'Orbigny from Marie Galante indicate the presence of Miocene beds on that small island, but it has not yet been confirmed. *Thracia guadalupensis* Dall and *T. spenceri* Dall (one species ?) apparently are the only Tertiary mollusks recorded from Guadeloupe. It is not certainly known whether they were collected from Miocene beds, evidence for the presence of which is discussed by Vaughan (U. S. Nat. Mus. Bull. 103, p. 592, 1919).

The Miocene mollusks from Martinique described by Cossmann are rather poorly preserved. He describes 27 species, 22 of which are named. Virtually none of Cossmann's identifications with previously described species can be accepted. He considers that the Martinique beds and the Gatun formation are of the same age, probably middle Miocene, but he calls the Bowden formation Aquitanian and the Miocene beds of the Dominican Republic upper Miocene, not knowing that several horizons are represented in the Dominican beds. Probably no Bowden species is found at Martinique, and the beds that carry these mollusks may represent the upper part of the lower Miocene or the lower part of the middle Miocene.

MEXICO

Papers dealing with the Miocene mollusks of the Atlantic coast of Mexico are as follows:

Literature list, Mexico

Dall 1890-1903	Sheldon 1917
Böse 1906	Berry 1922
Böse and Toula 1910	Hanna 1924
Engerrand and Urbina 1910	Woodring 1926
Toula 1911	Palmer 1927

Only one of these reports (Woodring 1926) deals with the Tuxpan formation of the Tampico embayment and it considers only one species (*Clementia grayi* Dall). Dickerson and Kew (Proc. California Acad. Sci., ser. 4, vol. 7, table opposite p. 128, 1917; Bull. Geol. Soc. America, vol. 28, pp. 224–225, 1917) listed mollusks from the Tuxpan formation and older Tertiary deposits of the Tampico embayment, but many of the determinations are unreliable. The Tuxpan formation carries *Chlamys condylomatus* (Dall), *Clementia grayi* Dall, and other Chipola species. Its correlation with the lower Miocene Chipola formation seems well established.

All the other reports in the preceding list deal with the Isthmus of Tehuantepec and adjoining regions. The following composite section is based on an interpretation of the mollusks that these beds carry:

Composite Miocene section for Isthmus of Tehuantepec and adjoining parts of Mexico

Time division	Formation and localities
Middle Miocene	Tuxtepec, Oaxaca, and Barranca de Santa Maria Tatetla, Vera Cruz
	Santa Rosa, Vera Cruz, and Zuluzum, Chiapas
Lower Miocene	Coatzacoalcos formation, Vera Cruz

J. W. Spencer (Bull. Geol. Soc. America, vol. 9, pp. 23, 25, 1897) gave the name Coatzacoalcos formation to the beds cropping out at places on the Tehuantepec Railroad, the mollusks from which have been described by Dall (1890–1903), Böse (1906), Böse and Toulia (1910), and Toulia (1911). These beds carry a peculiar cool-water and deep-water fauna, including an undescribed *Fusoterebra*, a relatively gigantic *Bathysarca*, *B. spenceri* (Dall), and the only Miocene *Astarte* from tropical America, *A. opulentora* Dall. It is difficult to determine just what part of the lower Miocene these beds represent, for the fauna is not comparable with any other. It may represent the Chipola and Baitoa formations. At all events apparently none of the species is also found at Bowden.

Böse (1906) described five species of mollusks from Santa Rosa, Vera Cruz, a locality near the border of Oaxaca along the branch of the National of Mexico Railroad that leads off from the Tehuantepec Railroad at Santa Lucrecia. Dr. Bruce Wade, while engaged in work for the Transcontinental Petroleum Company, obtained a collection of about 300 species of mollusks from the Santa Rosa beds. An

account of this material is being prepared by Mr. R. E. L. Collins of Johns Hopkins University. These beds carry an *Aphera* like *A. islacolonis* Maury, and an *Anadara* closely resembling *A. corcupidonis* (Maury) is extraordinarily abundant. The only American *Spirulirostra*, *S. americana* Berry, is based on material from these beds. They also carry the northernmost Caribbean representative of *Turritella* "*robusta*" Grzybowski. Some of the Santa Rosa species will turn out to be the same as Bowden species, but there is no doubt that the Santa Rosa beds are older than the Bowden formation and they are considered to be of the same age as the Cercado formation.

The mollusks described by Engerrand and Urbina from Zuluzum, a locality near Palenque, Chiapas, east of the Isthmus of Tehuantepec, are considered as representing the same horizon as the Santa Rosa beds, but the evidence is not very conclusive. I have never seen this paper mentioned in reports dealing with the Miocene mollusks of tropical America, except in Sheldon's compilation of the Arcas. "*Arca* (*Scapharca*)" *chavezii* Engerrand and Urbina probably is the name to use for the very abundant *Cardium*-like "*Arca*" of the Santa Rosa beds. "*Scapharca*" *corcupidonis* Maury may be a synonym. Engerrand and Urbina record *Cancellaria barretti* Guppy, "*Phos*" *elegans* Guppy, and *Chione woodwardi* (Guppy), all of which are Bowden species, from this locality, but the material on which these records are based is not described or figured.

Böse (1906) described 31 species of mollusks from Tuxtepec, which lies in Oaxaca, a short distance beyond the border of Vera Cruz. These beds clearly represent the horizon of the Gatun formation and, therefore, are considered middle Miocene and fall closer to the horizon of the Bowden formation than the preceding localities. Tuxtepec is the type locality of *Conus* "*agassizi*" *multiliratus* Böse. This species is one of the most characteristic middle Miocene species in the whole Caribbean region. The form in the Gatun, Gurabo, and Bowden formations is slightly different and takes the name *C. multiliratus gaza* Johnson and Pilsbry. "*Venus* (*Chione*)" *ebergenyii* Böse probably is a synonym of *Chione mactropsis* (Conrad), a characteristic Gatun species. Böse's "*Sconsia sublaevigata* Guppy" seems to be *S. laevigata* (Sowerby), which is found in the Gatun and Gurabo formations. "*Phos*" *mexicanus* Böse, a *Cancellaria*-like "*Phos*," closely resembles "*Phos*" *gatunensis* Toulou. "*Solarium*" *villarelloii* Böse is considered a synonym of *Architectonica nobilis quadriseriata* (Sowerby), a Gurabo and Bowden form. Böse records *Pecten bowdenensis* Dall from this locality, but it does not seem to be quite the same as the Bowden *bowdenensis*.

Böse's (1906) Santa Maria Tatetla locality, which lies near Huatusco, Veracruz, may represent the same horizon, but the material is not so well preserved.

Collections in the United States National Museum show that the middle Miocene Tuxtepec horizon is found at a large number of localities in the Tehuantepec region, in the states of Vera Cruz, Oaxaca, and Chiapas. According to a hasty examination, these collections contain *Conus molis* Brown and Pilsbry, *Conus imitator* Brown and Pilsbry, which may be a synonym of *C. almagrensis* Böse, *Conus multiliratus* Böse, "*Phos*" *mexicanus* Böse, *Sconsia laevigata* (Sowerby), *Distorsio clathratus gatunensis* (Toula), *Turritella tuxtepecensis* Böse, an *Anadara* like *A. actinophora* (Dall), and *Chione ebergenyii* (Böse). Collections from Arroyo Chapapoapan in the Sayula district, Vera Cruz, which is not to be confused with another Sayula in Chiapas, are placed here. They contain among other things *Conus imitator* Brown and Pilsbry and a *Metula* like *M. gabbi* Brown and Pilsbry. The only record of Sayula fossils that I know of is in Bulletin 103 of the United States National Museum, in which Pilsbry (pp. 185-186) records a Pliocene barnacle and the beds are called Pliocene. The same barnacle is also recorded from U. S. G. S. stations 5903 and 5906a, localities on the Chagres River near Alhajuela, east of the Canal Zone, where beds of Miocene age crop out.

This Mexican material should be described, as it comes from a critical region between Central America and Florida and offers the best means of comparing the Miocene deposits in these two widely separated regions.

CENTRAL AMERICA

GUATEMALA

No Miocene mollusks are described from any localities in the long stretch from Chiapas to Costa Rica, though they will probably be found in Yucatan and northern Guatemala.

Collections in the United States National Museum from a limestone on Rio Dulce, Guatemala, carry *Orthaulax aguadillensis* Maury and other poorly preserved mollusks, principally in the form of molds. This limestone seems to represent the lower Miocene Anguilla horizon, a conclusion that is sustained by the evidence furnished by the foraminifera and corals. Vaughan has already recorded the opinion that this limestone "probably represents a horizon very near that of the Emperador limestone" (U. S. Nat. Mus. Bull. 103, p. 586, 1919).

Lignite-bearing beds on Rio Carboneras carry a brackish- and fresh-water fauna consisting of *Pachycheilus*, *Tryonia*?, "*Unio*," and *Cyrenoida*. Dall briefly mentioned this occurrence of *Cyrenoida* and *Tryonia* (Nautilus, vol. 37, p. 98, 1924). These beds also probably are Miocene, but they may be as young as Pliocene.

COSTA RICA AND ADJOINING PARTS OF BOCAS DEL TORO PROVINCE, PANAMA

The literature list for the Atlantic coast of Costa Rica and adjoining parts of Panama is as follows:

Literature list, Costa Rica and adjoining parts of Panama

Gabb 1861	Sheldon 1917
Gabb 1881	Maury 1917
Gabb 1881a	Pilsbry and Johnson 1917
Dall 1890-1903	Pilsbry 1922
Guppy and Dall 1896	Olsson 1922
Pilsbry and Sharp 1897-98	Palmer 1923
Grabau 1904	Dall 1925
Pilsbry 1911	Woodring 1926
Dall 1912	Palmer 1927
Brown and Pilsbry 1913	

For convenience reports dealing wholly with the Pliocene beds of Costa Rica are included in this list.

The basin in which the Miocene beds were deposited extends at least from the latitude of Port Limon southeastward into Panama a short distance beyond Chiriqui Lagoon. During lower Miocene time it extended across central Costa Rica, and the Atlantic and Pacific Oceans were united. The Miocene deposits of the interior of Costa Rica are discussed later in the matter dealing with the Pacific coast.

Olsson's report is the most extensive one on Costa Rican Miocene fossils. Unfortunately it contains only an outline of the stratigraphy and hardly any precise locality records. His collections are from Port Limon, Rio Blanco, Rio Banana, Rio Betey (Biscay ?), and Rio Estrella and its tributaries; from several small streams entering the Caribbean Sea near Cahuita and Old Harbor (Puerto Viejo) between Rio Estrella and Punta Mona; from several islands in the Bocas del Toro archipelago, that is, in Almirante Bay and Chiriqui Lagoon; and from Coco Plum, a locality on the Panama coast "about 40 miles east of Bocas del Toro." All these localities, except Coco Plum and the islands in the Bocas del Toro archipelago, lie north of the ridge along the north side of the Talamanca Valley—a name given to the basin drained by Rio Sixaola and its numerous tributaries, the seaward part of which straddles the Costa Rica-Panama boundary. Pittier's map of Costa Rica (Petermann's Mitt., *Ergänzungsband* 37, *Ergänzungsheft* 175, 1912) and the map of Panama compiled by Sabas A. Villegas, of Panama City, in cooperation with the American Geographical Society, show most of these localities. The United States National Museum has collections from many of these localities, and also from others in the Talamanca Valley and south of it. These collections were made by Olsson, myself, and others during explorations for the Sinclair Central American Oil Corporation under the direction of Dr. Donald F. MacDonald. Large collections from Rio Banana were

made at an earlier date by MacDonald, and collections from the region around Port Limon were presented by Pittier and Wailes. All this material has been utilized in the following summary.

The Uscari formation, named by Olsson, comprises the lowest Miocene beds in this region. At the type locality on Uscari Creek it consists of strongly deformed shales that carry only a few very poorly preserved mollusks. It is a rather unfortunate choice for a type locality, for Olsson records no species from it. Without any discussion, but presumably on stratigraphic grounds, he records 11 species from the Uscari formation at Coco Plum and on several of the small streams flowing northeastward from the ridge along the north side of the Talamanca Valley. Three additional species are based on Gabb's descriptions of mollusks from Sapote (or Zapote) on Rio Revantazon, a locality that Olsson places in the Uscari formation. Gabb (1881a) described 33 species of mollusks from this locality, which apparently has not been revisited. His collection stands in urgent need of revision. So far as present material goes the Sapote beds should be regarded as the type lower Miocene of Costa Rica. They carry *Clementia dariena* (Conrad), which also is found in the lower part of the Gatun formation of the Panama Canal Zone and of Costa Rica, but the most striking species is a "Phos"-like mollusk called *Phos inornatus* by Gabb. The Uscari formation also crops out along the southern border of the Talamanca Valley. "*Arca* (*Barbatia* ?)" *oronlensis* Gabb, and *Turritella tristis* Brown and Pilsbry, both from "Oronli Creek," a tributary of Rio Uren, which in turn flows northward into Rio Sixaola, probably were collected from the Uscari formation. The Sapote beds seem to represent the Baitoa horizon. The Uscari species recorded by Olsson elsewhere than at the type locality resemble Cercado species and may represent a younger zone.

The Gatun formation, which carries most of the 334 Costa Rican species described by Olsson, overlies the Uscari formation. In the region of the type locality of the Uscari formation the Gatun formation unconformably overlies it. Elsewhere, according to Olsson, the contact is a disconformity. At places the Gatun formation overlaps the Uscari formation and rests directly on much older rocks. The boundary between these two formations is a convenient place for the boundary between lower and middle Miocene. According to Olsson, the Gatun formation of Costa Rica includes higher beds than any in the Gatun formation of the Panama Canal Zone. The time interval, however, probably is the same when the whole basin, of which the Atlantic side of the Canal Zone is only a part, is considered, as will be discussed later, even though the beds are much thicker in Costa Rica. Olsson discusses the different facies of the Gatun formation in Costa Rica. The landward facies consists of coastal swamp clays and lignite, and of heavy conglomerates and coarse sandstones.

The seaward facies comprises coralliferous limestones that were deposited in clearer and for the most part deeper water. Between them siltstone and fine sandstones are found.

The coastal swamp muds furnished the brackish-water mollusks described by Gabb in 1861, including "*Arca*" *chiriquiensis* Gabb and a *Potamides* that Gabb called *Terebra evansii*, and also "*Arca*" *dolaticosta* Pilsbry and Johnson. Both these Arcas are brackish-water Senilias. This material was collected during explorations to determine the extent of the lignite deposits, and is not necessarily from the immediate vicinity of Chiriqui Lagoon (see Evans, Geological Report; Report Chiriqui Commission, 36th Congress, 2nd Ses., House Ex. Doc. 41, pp. 45-55, 1861). We collected specimens of *Senilia dolaticosta* on a small eastward-flowing stream entering Rio Yorkin, which forms the boundary between Panama and Costa Rica, near its mouth.

Bowden mollusks recorded from Uscari and Gatun formations of Costa Rica

SPECIES	Uscari forma- tion	Gatun formation	
		Landward facies	Seaward facies
Gastropods:			
Aceton textilis Guppy.....	X	X	
Volvula oxytata Bush.....			
Carinodrillia bocatoroensis (Olsson).....			X
Ancistrosyrinx miranda (Guppy).....		X	
Lioglyphostoma moinica (Olsson).....			X
Conus proteus Hwass.....		X	X
Conus stenostoma Sowerby.....			X
Conus planiliratus Sowerby.....			X
Conus mutiliratus gaza Johnson and Pilsbry			X
Conus granozonatus Guppy.....		X	
Conus gracilissimus Guppy.....			X
Latirus infundibulum polius Woodring....		?	
Tritiaria moorei (Guppy).....		X	
Columbella submercatoria Olsson.....		X	
Strombina guppyi Woodring.....		X	
Murex recurvirostris Broderip.....		X	X
Typhis alatus obesus Gabb.....			X
Distorsio clathratus gatunensis (Toula)....		X	X
Bursa proavus bowdenensis Pilsbry.....		?	
Cassis sulcifera Sowerby.....		X	
Semicassis reclusa (Guppy).....		X	
Malea camura Guppy.....	X	X	
Alaba turrita Guppy.....		X	
Lemintina papulosa (Guppy).....		X	

Bowden mollusks recorded from Uscari and Gatun formations of Costa Rica—Continued

SPECIES	Uscari forma- tion	Gatun formation	
		Landward facies	Seaward facies
<i>Crepidacella cepula</i> (Guppy).....			×
<i>Polinices brunnea subclausa</i> (Sowerby)....		×	
<i>Astraea brevispina basilis</i> (Olsson).....		×	
<i>Tricolia umbilicata</i> (d'Orbigny).....		×	
<i>Smaragdia viridis viridemaris</i> (Maury)....		×	
Pelecypods:			
<i>Glycymeris jamaicensis</i> Dall.....		×	×
" <i>Arca</i> " <i>occidentalis</i> Philippi.....			×
" <i>Arca</i> " <i>bowdeniana</i> Dall.....			×
<i>Pteria inornata</i> Gabb.....	×	×	
<i>Ostrea costaricensis</i> Olsson.....		×	
<i>Limea solida</i> Dall.....		×	
<i>Placunanomia lithobleta</i> Dall.....		×	
<i>Myrtaea limoniana</i> Dall.....		×	×
<i>Phacoides actinus</i> Dall.....			×
<i>Cardium medium</i> Linné.....			×
<i>Cardium serratum</i> Linné.....		×	
<i>Antigona blandiana</i> (Guppy).....		×	×
<i>Strigilla pisiformis</i> (Linné).....		×	
<i>Abra triangulata</i> Dall.....			×
<i>Corbula viminea</i> Guppy.....		×	
<i>Rocellaria rotunda</i> (Dall).....		×	

This stream was called "Shuab Creek" in an attempt to transcribe the Indian name, but Gabb (Informe sobre la exploración de Talamanca verificado durante los años de 1873-74, p. 65, San José, 1894) called it "Shoai." MacDonald collected the large *grandis*-like *Senilia* from "Carbon Creek," a small southeastward-flowing stream entering Rio Sixaola east of Chase Farm of the United Fruit Company, making three species of *Senilia* for this region. *Potamides evansii* has been ignored. *P. cahobasensis* Pilsbry, a Haitian species, is very similar to it and may turn out to be a synonym.

The detrital landward facies of the Gatun formation consists of one or more conglomerates and coarse sandstones, above which lie siltstones. "*Pecten*" *levicostatus* Toulou is the most abundant fossil in the sandstones. The plants described by Berry (Proc. U. S. Nat. Mus., vol. 59, pp. 169-185, 1921) were collected from float material derived from beds lying immediately above a basal conglomerate. The

siltstones lying higher in the section or lying at the same horizon farther seaward carry the greatest number of mollusks found in any of the beds of the landward facies. Collections from these beds have been made both north and south of the Talamanca Valley, but south of it the structure is much more complicated. The largest collections are those from Rio Banana made by MacDonald, and when these collections are studied a considerable number of species will be added to the Costa Rican Gatun fauna. Olsson (pp. 187-188) lists some of the most abundant and most characteristic species.

The seaward facies of the Gatun formation is found principally at Port Limon, on some of the islands of the Bocas del Toro archipelago, and on Valiente Peninsula at the east end of Chiriqui Lagoon. Olsson (p. 188) lists some of the characteristic species of this facies, which carries a fauna that in many features differs from the fauna of the landward facies.

The Pliocene beds at and near Limon were confused with the Miocene beds by some of the earlier writers. They carry the only large Pliocene fauna so far known from the Caribbean region, and this material will be particularly valuable in attempting to trace the lineage of the Miocene species. Probably most of the 137 species described by Gabb (1881a) will turn out to be from these Pliocene beds. It is estimated that 50 or 60 per cent of the species in this fauna are Recent species. *Metula*, represented by a species very similar to *M. cancellata* Gabb, from the Gurabo formation, seems to be the only exotic genus in these Pliocene beds. According to collections in the United States National Museum, Quaternary marine beds also crop out near Limon.

Many Bowden species are found in the Gatun formation of Costa Rica. Those listed on pages 70 and 71 are already recorded, and others, especially among the small species, will be added when all the available material is studied. Three Bowden species recorded from the Uscari formation are also listed.

Of the 43 definitely identified species in this list 29 are found in the landward facies, 20 in the seaward facies, and 7 in both. On the face of this list the Bowden mollusks seem to be more similar to those of the landward facies. I am inclined to believe, however, that the evidence would be in favor of a closer similarity to the seaward facies if material representing as large a percentage of the whole fauna then living as is found in the Bowden formation were available for both facies. Olsson reached this conclusion. Most of the cones and *Crepidacella* show a similarity with the seaward facies. How much weight is to be given to the facies difference of contemporaneous deposits and how much to difference in age between the landward and seaward beds in Costa Rica is open to question. Olsson emphasizes both. Although some of the seaward deposits may be of the same age as the landward beds, most of them probably are a little younger. This conclusion is

supported by the transgression of the seaward facies along part of the Panama coast. Although the evidence as it now stands is not entirely conclusive, the Bowden formation is considered the equivalent of the seaward Gatun beds of Costa Rica. Whether these beds are to be considered upper Miocene, as Olsson was inclined to believe, is a matter of opinion as to where the boundary between middle and upper Miocene is to be drawn. Considering the Miocene deposits of the entire Caribbean region it seems more reasonable to place both these beds and the Bowden formation at the top of the middle Miocene. More precise correlation with the Florida section may alter this conclusion. A large collection from Port Limon, collected by Olsson (U. S. G. S. station 8343) is different from the Miocene material recorded from that locality. This collection may represent an upper Miocene horizon.

Though the Bowden formation is considered as representing approximately the same time interval as the seaward facies of the Gatun formation, it does not carry some of the most characteristic Costa Rican genera. It carries no species of *Fusoterebra* and *Leucosyrinx*, found in the seaward facies, no species of *Aphera*, *Cunearca*, *Noetia*, *Dosinia*, *Macrocallista*, *Mactrella*, *Harvella*, and *Mulinia*, which are abundant in the landward facies, and no species of "*Turricula*," *Agaronia*, *Voluta*, *Solenosteira*, *Lophocardium*, and *Clementia*, which are found in both. The absence of some of these genera may be due to the absence of a mud facies at Bowden, but the absence of others, and of many Gatun species representing genera found in the Bowden formation, is believed to be due to geographic location. It will be shown in the discussion of the Gatun formation of the Panama Canal Zone and of beds of the same age in northern South America that the Gatun fauna is a well-recognized unit, but that on the Atlantic side it is confined to the western and southern borders of the Caribbean Sea.

PANAMA CANAL ZONE AND ADJOINING PARTS OF COLON PROVINCE, PANAMA

The following is a list of reports dealing with the Miocene mollusks of the Panama Canal Zone. None has yet been issued on adjoining parts of the Province of Colon.

Literature list, Panama Canal Zone

Conrad 1855	Dall 1912	Hanna 1924
Conrad 1856	de Boury 1912	Dall 1925
Gabb 1881	Brown and Pilsbry 1913	Maury 1925
Dall 1896	Cossmann 1913	Hodson 1926
Guppy and Dall 1896	Sheldon 1917	Woodring 1926
Dall 1890-1903	Cooke 1921a	Palmer 1927
Toula 1909	Hubbard 1921	F. Hodson, H. K. Hod-
Brown and Pilsbry 1911	Olsson 1922	son, and Harris 1927
Toula 1911a		

In several of these reports (Dall 1912, de Boury 1912, Dall 1925) the only Panama material considered may be of Pliocene age.

The stratigraphy of the Tertiary deposits of the Panama Canal Zone and also the fossils, except the mollusks, are described in Bulletin 103 of the United States National Museum (Vaughan and others, Contributions to the geology and paleontology of the Panama Canal Zone, 1918-19). The mollusks are so numerous that they had to be almost disregarded in this publication. Though the preceding list shows that many reports have been issued on the mollusks, most of the species still remain undescribed, or at least are not recorded from the Canal Zone. The United States National Museum has a set of collections made by MacDonald and by Vaughan and MacDonald during the construction of the canal. Many of the localities are now under water and will be inaccessible so long as the canal is in use. Other large collections, principally from localities near Mt. Hope and west of Gatun Lake and Chagres River, were made by Olsson during explorations for the Sinclair Central American Oil Corporation. Altogether it is an unusually fine set of collections, which I hope to describe.

The Miocene section in the Canal Zone and adjoining parts of the Province of Colon west of the Zone, as here presented, is as follows:

*Miocene section in Panama Canal Zone and adjoining parts of
Province of Colon*

Time subdivision	Formations		Probable equivalents
Upper Miocene or Pliocene	Toro limestone		?
Middle Miocene	Gatun formation	Upper part	Bowden formation
		Middle part	Gurabo formation
		Lower part	
	Vamos-a-Vamos beds		Cercado formation
Lower Miocene	Emperador limestone and upper part of Culebra formation		Anguilla formation

Only seven species of mollusks have so far been described from the Culebra formation, but one of them has already had three names

(*Arca dalki* Brown and Pilsbry 1913, *Arca balboai* Sheldon 1917, and *Arca invalida* Hanna 1924). Aside from the record of *Orthaulax gabbi* Dall (Cooke 1921a) and the doubtful record of *Clementia dariena* (Conrad) (Woodring 1926), these species were described or listed by Brown and Pilsbry, whose "lignitic layers near Tower N, Las Cascadas" represent the Culebra formation. Much of the Culebra material is poorly preserved, but it is estimated that between 100 and 150 species of mollusks are represented, most of which are not found in other beds, except in the Emperador limestone. These collections of mollusks represent only the upper part of the Culebra formation. Brown and Pilsbry record *Turritella altilira* Conrad from the Culebra formation, but none of the specimens seem to be quite the same as the Gatun *altilira*. The *Orthaulax* from U. S. G. S. station 6515 (west side of canal about one-third of a mile north of Paraiso) recorded by Cooke as *O. gabbi* Dall may be *O. aguadillensis* Maury. "*Nassa*" *praeambigua* Brown and Pilsbry, *Bittium scotti* Brown and Pilsbry, a *Turritella* of lower Miocene type, several *Pecten*s, *Spondylus scotti* Brown and Pilsbry, a large *Trachycardium*, and a *Chione* are abundant in many of the collections. It probably will be possible to recognize two faunal zones in the upper part of the Culebra formation, the upper one of which, represented by U. S. G. S. stations 5901, 6025, and 6026 (for data on 6025 and 6026 see U. S. Nat. Mus. Bull. 103, pp. 540-541, 1919) carries *Orthaulax gabbi* Dall, a *Turritella* very close to *altilira* and a *Flabellipecten* that probably is *P. gatunensis* Toulia. It is expected that most of the upper part of the Culebra formation on the basis of the mollusks will be correlated with the Anguilla formation, which agrees with Vaughan's conclusion (U. S. Nat. Mus. Bull. 103, pp. 208, 585, 1919), but the "upper zone," which may correspond to the Caimito formation, may be considerably younger.

The only mollusks so far recorded from the Emperador limestone are the 13 species from the "Pecten bed at tower N, Las Cascadas" (Brown and Pilsbry 1913, p. 503). Probably 50 species of mollusks are represented in the Emperador collections, many of which are also found in limy beds in the upper part of the Culebra formation. "*Pecten*" *canalis* Brown and Pilsbry and *Amusium sol* Brown and Pilsbry are particularly abundant. The Emperador *Orthaulax*, recorded by Cooke as *O. gabbi* Dall, is considered as representing *O. aguadillensis* Maury. So far as the mollusks are concerned there is no basis for considering the Emperador limestone as younger than the "lower faunal zone" of the upper part of the Culebra formation. It seems to represent patches of reef limestone in the upper part of the Culebra formation (see Vaughan, U. S. Nat. Mus. Bull. 103, p. 585, 1919). It should be pointed out that the Culebra formation and Emperador limestone carry the youngest American species of *Lepidocyclina*. This genus has not yet been found in the Anguilla and Tampa forma-

tions, which are supposed to be of the same age as these Canal Zone formations.

The Miocene beds of the Canal Zone extend eastward up the Chagres River far beyond the limits of the Zone, at least almost as far as the mouth of Rio Pequeni. Just what part of the section they represent has not yet been determined. Some of these beds may be younger than the Culebra formation and Emperador limestone.

The locality from which Hill, and also Vaughan and MacDonald, collected at Vamos-a-Vamos is now under water. The beds at this locality are described by Hill and by MacDonald (Bull. Mus. Comp. Zool. Harvard College, vol. 28 (geol. ser., vol. 3), pp. 179–180, 1898; U. S. Nat. Mus. Bull. 103, p. 542, 1919). Dall reported that the fossils from the Vamos-a-Vamos beds are Eocene (in Hill, pp. 271, 273), but Hill (p. 207) could not quite understand how these beds could be older than the foraminiferal marls at Bujio (Bohio), which belong in the Culebra formation. Vaughan and MacDonald assumed that they represent the Gatun formation. Dall was justified in believing that they are older than the “Monkey Hill beds” (Gatun formation), but the poor preservation of most of the material was misleading. These beds carry *Turritella altilira* Conrad, *T. gatunensis* Conrad, “*Arca*” *dariensis* Brown and Pilsbry, *Clementia dariena* (Conrad), and *Chione mactropsis* (Conrad), all of which are Gatun species, but a number of the Vamos-a-Vamos species—*Glyptostyla panamensis* Dall, a *Morum*, several naticoids, *Cardium gatunense* Dall, “*Pitaria*” *hilli* Dall, and *Mactra dariensis* Dall—are not found in the Gatun formation. These beds, instead of the “upper faunal zone” of the Culebra formation, may represent the Caimito formation. At all events they are older than the Gatun formation and are considered the equivalent of the Cercado formation. The absence of the Vamos-a-Vamos beds, except at a locality that is now inaccessible, is attributed to the overlap of the Gatun formation.

The Gatun formation carries a far greater number of species of mollusks than any of the Canal Zone formations so far described. From a preliminary examination of the Gatun collections it is estimated that about 400 species are represented, more than half of which are undescribed or are not recorded from the Canal Zone. The basin in which the Gatun formation was deposited extends eastward a short distance into Panama and southwestward along the coast for a distance of at least about 25 miles beyond the border of the Zone. Three faunal zones can be recognized corresponding to the lower, middle, and upper parts of the formation. The lower zone is represented in the railroad cuts near Gatun station, in the Quebrancha Hills, and in the excavations for the Gatun locks. *Clementia dariena* (Conrad) is confined to this zone, so far as the Gatun formation is concerned. The middle zone is represented at Mindi and Mt. Hope, and also

west of Gatun dam and on the Chagres River below the spillway. Many of Toula's species came from this zone, which embraces the uppermost Gatun beds from which fossils were collected within the Canal Zone. *Cancellaria dariena* Toula, *Strombina lessepsiana* Brown and Pilsbry, and "*Arca*" *actinophora* Dall are abundant in this zone, but are not found in the lower zone. Many of the common Gatun species are found in both zones ("*Drillia*" *gatunensis* Toula, *Conus molis* Brown and Pilsbry, *Conus imitator* Brown and Pilsbry, *Oliva gatunensis* Toula, "*Phos*" *gatunensis* Toula, *Turritella gatunensis* Conrad, *Turritella altilira* Conrad, "*Solarium*" *gatunensis* Toula, "*Natica*" *guppyana* Toula, "*Arca*" *dariensis* Brown and Pilsbry, and *Chione mactropsis* (Conrad)). The upper faunal zone is represented along and near the coast west of the Canal Zone. It is by far the most distinctive of the three zones, as it carries a large number of species and genera not found in the lower and middle zones. It seems to be the equivalent of the seaward facies of the Gatun formation in Costa Rica and adjoining parts of the Province of Bocas del Toro, Panama. The same question arises here as to how much of the difference is due to facies and how much to age. Though the upper zone probably represents deeper and clearer water, it seems to be younger than the other zones. On Rio San Miguel it rests directly on the basement igneous rocks, apparently overlapping the part of the formation cropping out in the Canal Zone.

Not enough work has yet been done on the Gatun mollusks to compare them satisfactorily with those from the Bowden formation. The following species are recorded from both:

Bowden species recorded from Gatun formation

<i>Conus proteus</i> Hwass	<i>Polinices brunnea subelauza</i> (Sowerby)
<i>Conus multiliratus</i> gaze Johnson and Pilsbry	<i>Sinum gatunense</i> (Toula)
<i>Conus consobrinus</i> Sowerby	<i>Cardilum serratum</i> Linné
<i>Murex recurvirostris</i> Broderip	<i>Pitar gatunensis</i> (Dall) (see p. 21)
<i>Distorsio clathratus gatunensis</i> Toula	<i>Pitar carbaseus</i> (Guppy)
	<i>Corbula sericea</i> Dall ?
	<i>Corbula heterogena</i> Dall

Other species, especially small ones, will be added when the Gatun collections are described. Inasmuch as the Gatun formation of the Canal Zone clearly is the equivalent of the landward facies of the Gatun formation in Costa Rica, and inasmuch as the upper zone represents the seaward facies in Costa Rica, it is concluded that the Bowden formation is the approximate equivalent of the upper zone. It is not expected, however, that many Bowden species will be found in the upper zone, for no matter what Miocene stages are compared, the fauna of the southwest end of the Caribbean Sea is different from that of the north edge. The lower and middle zones of the Gatun

formation are considered the equivalent of the Gurabo formation. *Conus haytensis* Sowerby is the Gurabo analogue of the Gatun *C. molis* Brown and Pilsbry. Another Gatun cone resembles *C. symmetricus* Sowerby, the most abundant cone in the Gurabo formation. *Cypraea henekeni* Sowerby is found in both the Gatun and Gurabo formations. Records of such species, which seem to have no particular facies significance and which are not found at Bowden, are considered evidence that the Bowden formation differs in age from the Gurabo formation and from the Gatun formation of the Canal Zone. The Gatun fauna is remarkable for the large number of Cancellarias (about 13 species) and also for the large number of *Phos*-like mollusks (about 9 species).

The Gatun formation does not extend across the Isthmus like the underlying Emperador limestone and Culebra formation. No fossils have so far been recorded from the Panama formation, which is regarded as the equivalent of the Gatun formation on the Pacific side. MacDonald collected near Paraiso (U. S. G. S. station 6336) from a light-colored tuff in the stratigraphic position of the Panama formation an exterior mold of an *Acila* that probably is the Gatun species *A. isthmica* (Brown and Pilsbry), and another mold that may represent a fresh-water mussel.

About 25 species, mostly in the form of molds, are represented in collections from the Toro limestone. *Sthenorytis toroensis* (Dall), of which *S. chaperi* de Boury is a synonym, *S. toroensis insignis* Dall, and *Pecten macdonaldi* Olsson are the only Toro species so far described. Whether the Toro limestone is upper Miocene or Pliocene can hardly be determined from this material. It was called Pliocene in Bulletin 103 of the United States National Museum. Inasmuch as it unconformably overlies the Gatun formation, no reason is apparent for changing this age assignment.

It might not be out of place to point out that the only specimens of "*Pecten*" *ventricosus* Sowerby from the Canal Zone were collected from Quaternary deposits on the Pacific side, not on the Atlantic side. Also no specimens of *Northia northiae* Gray are in the collections from Atlantic Quaternary deposits (see Dall, Smithsonian Misc. Coll., vol. 59, No. 2, p. 1, 1912; Olsson, Bull. Am. Paleontology, vol. 9, p. 192, 1922).

NORTHERN SOUTH AMERICA

COLOMBIA

The following papers, which account for only 41 species, deal with the Miocene mollusks of Colombia:

Literature list, Colombia

Pilsbry and Brown 1917
Woodring 1926
Anderson 1927

Palmer 1927
F. Hodson, H. K. Hodson, and
Harris 1927

The following summary, which is based on work done in 1923 for the Tropical Oil Company, is published with the permission of Dr. O. B. Hopkins, Chief Geologist of the Imperial Oil Co. (Ltd.).

Marine Miocene deposits are found over a large part of the coastal region of Colombia and extend far up the valleys of Rio Magdalena, Rio Sinu, and Rio Atrato. About 400 species of mollusks are represented in collections from these beds. The lowest Miocene deposits from which fossils were collected crop out in the valley of Rio Sinu. A large *Dinocardium*, a *Nodipecten* like *C. condylomatus* (Dall), and a peculiar "Phos" resembling "Phos" *inornatus* Gabb are characteristic of these beds, which are considered of lower Miocene age. They are younger than the Culebra formation and Emperador limestone of the Panama Canal Zone and seem to be the equivalent of the Baitoa, Thomonde, and Chipola formations, and also of Gabb's Sapote beds of Costa Rica.

An unmistakable fauna corresponding to that of the Gatun formation of the Panama Canal Zone is found almost throughout the coastal region. *Conus molis* Brown and Pilsbry, *Oliva gatumensis* Toulou, *Turritella gatumensis* Conrad, *Clementia dariena* (Conrad), and *Chione mactropsis* (Conrad) are some of the Gatun species that are abundant in these beds. *Glycymeris tumefactus* Pilsbry and Brown and *Antigona caribbeana* Anderson are confined to beds lying below those carrying the Gatun fauna. These beds are considered middle Miocene, and also those that carry the Gatun fauna. A giant *Turritella*, *T. "robusta"* Grzybowski, is found in both middle Miocene zones. Fossils from El Banco, which lies on Rio Magdalena about 150 miles in a direct line above its mouth, are considered of middle Miocene age, though most of the species are different from those in the coastal region.

Upper Miocene beds crop out in the vicinity of Usiacuri. Preliminary lists of some of the mollusks from these beds have been published (U. S. Nat. Mus. Bull. 103, pp. 588-589, 1919). The type of *Sep-tastrea matsoni* Vaughan (U. S. Nat. Mus. Bull. 103, pp. 411-412, 1919), which is very similar to *S. marylandica* (Conrad), from the Yorktown formation of Virginia, was collected from these beds. They lie several thousand feet above those carrying a Gatun fauna and are considered younger than any part of the Gatun formation. *Turritella cartagenensis* Pillsbry and Brown (probably a synonym of *T. bifastigata* Nelson), *Turritella lloydsmithi* Pilsbry and Brown, and *Glycymeris canalis trilobica* Pilsbry and Brown are abundant in these beds. Some Gatun species, notably *Conus molis* Brown and Pilsbry, are found in these upper Miocene beds, but their fossils show a distinct faunal change. A collection from a locality far up Rio Atrato about 40 miles below Quibdó represents the upper Miocene beds, or possibly the middle Miocene ones.

The giant *Senilia* that is remarkably like the Recent Panamic *S. grandis* (Broderip and Sowerby) occurs throughout the Miocene

section. The smaller *Senilia chiriquiensis* (Gabb) is found in middle Miocene beds that carry a considerable number of brackish-water species. Both these *Arcas* are widely distributed in the Miocene deposits of the West Indies, Central America, and northern South America.

Pilsbry and Brown record the following Bowden species from Colombia:

*Bowden species recorded from Colombia*¹

Conus multiliratus gaza Johnson and Pilsbry

Murex pomum Gmelin

Semicassis reclusa (Guppy)

Polinices brunnea subclausa (Sowerby)

It is not expected that many other Bowden species will be found among the Miocene mollusks from Colombia. The Gatun fauna shows a remarkable unity from Costa Rica to Colombia, and to a less extent northward to the Isthmus of Tehuantepec in Mexico and eastward to Venezuela and Trinidad. Many of the species of this fauna that have an extensive distribution along the western and southern borders of the Caribbean Sea have never been found in the West Indies.

VENEZUELA

The literature list for Venezuela is as follows:

Literature list, Venezuela

Guppy 1866a	Aguerrevere 1925 (Pliocene ?)
Guppy 1867a	F. Hodson 1926
Dall 1890-1903	Woodring 1926
Guppy 1913	Palmer 1927
Sheldon 1917	F. Hodson, H. K. Hodson, and
Maury 1925	Harris 1927

Very little information about the Miocene stratigraphy of Venezuela is available in the literature.¹ The 51 *Turritellas* described by F. Hodson seem to be greatly overnamed, and because of economic interests precise locality and stratigraphic records were withheld, as in the more recent report by F. Hodson, H. K. Hodson, and Harris, which adds a great many names to the literature without contributing much to the geologic history of the region.

Some of the *Turritellas* described by Hodson (*hubbardi*, *larensis*, and *gilbertharrisii*) resemble species that elsewhere are found in beds now regarded as representing the lowermost Miocene zone (Anguilla horizon). Beds cropping out in the northern part of the State of Falcon, from which *Clementia dariena* (Conrad) has been recorded (Woodring 1926, p. 35), also are considered lower Miocene. They seem to be of the same age as the lower Miocene beds in the Sinu

¹ The Geology of Venezuela and Trinidad (552 pp., 83 pls., 22 figs., 1928), by R. A. Liddle, appeared while this account was in proof.

region of Colombia and, therefore, are correlated with the Baitoa, Thomonde, and Chipola formations. They carry the large *Dinocardium* that is very abundant in the Colombian beds.

Another collection from the Miranda District, Zulia, in the Maracaibo Basin (U. S. G. S. station 1/293), which contains the striking species *Turritella zuliana* Hodson, and also *T. venezuelana* Hodson (? *T. tristis* Brown and Pilsbry) and an *Alveinus* like the Chipola species *A. rotundus* Dall, represents about the same horizon.

No middle Miocene collections from the Venezuelan mainland are in the collections of the United States National Museum, excepting possibly some material in a collection in the Guppy collection labeled Cumana. It is assumed that *Turritella "robusta"* Grzybowski is found in middle Miocene beds, and that the group of *T. bifastigata* Nelson occurs in both middle and upper Miocene deposits, as in Colombia.

The following material in the Guppy collection is labeled Cumana. The names in this list are taken from the labels.

Species in Guppy collection labeled Cumana, Venezuela

Conus marginatus Sowerby ?	Turritella tornata Guppy (type material)
Pleurotoma barretti Guppy	
Oliva cylindrica Sowerby	Calyptrea scutellata
Marginella coniformis Sowerby	Arca pexata Say (changed to tolepiea Dall)
Marginella	
Fasciolaria tarbelliana Grat.	Arca incongrua Say (changed to cumanensis Dall; presumably type material)
Nassa solidula Guppy (type material)	
Columbella gradata crassa Guppy (type material; apparently a manuscript name)	Janira soror Gabb
Persona similima Sowerby	Cytherea juncea Guppy (type material)
Cerithium plebeium Sowerby	

In addition Guppy records "*Tornatina*" *coixlacryma* Guppy and *Crepitacella cepula* (Guppy), from Cumana. If all this material came from Cumana, it would be certain that middle Miocene beds of the age of the Bowden formation crop out there. *Acteocina coixlacryma*, *Turritella "tornata,"* and *Crepitacella cepula* are Bowden species. At least two of the specimens labeled "*Pleurotoma*" *barretti* represent *Polystira barretti*, *Oliva "cylindrica* Sowerby" is *O. reticularis trochala*, "*Persona similima* Sowerby" is *Distorsio clathratus gatunensis*, and "*Cerithium plebeium* Sowerby" is *Clava costaricana stena* Woodring, all of which are found at Bowden, making seven Bowden species recorded from Cumana. Inasmuch as most of these species have not yet been found elsewhere along the south edge of the Caribbean Sea, it would be very remarkable to get so many of them in one small collection. Moreover, the type of preservation and the matrix in

the two small specimens of "*Pleurotoma*" *barretti*, *Oliva* "*cylindrica*," "*Cerithium plebeium*," and *Turritella* "*tornata*" are so much like those of Bowden shells that it is safe to assume that they came from Bowden. The occurrence of *Acteocina coixlacryma* and *Crepidacella cepula* at Cumana is based only on Guppy's record and can for the present be eliminated. This leaves only one species, *Distorsio clathratus gatunensis*, which is also a Gatun species and would not look out of place in Venezuela. In confirmation of the view that this locality record is not trustworthy, it should be noted that there is no record of any one else having obtained such material at or near Cumana. "*Janira soror Gabb*" is the only one of Guppy's species that can be unequivocally accepted as a Cumana fossil. Several collections in the United States National Museum from a locality east of the castle at Cumana consist almost entirely of Pectens, including topotypes of the giant *P. arnoldi* Aguerrevere. These beds probably are of Pliocene age.

A collection from Margarita Island (U. S. G. S. station 6309, entrance to Boca Laguna de Marites, eight miles west of Palamar) contains a *Turritella* of the group of *T. gatunensis* Conrad, another species that probably is *T. plebeia alowensi* Hodson, and also a species of the group of *T. bifastigata* Nelson. This material is considered middle Miocene. No Miocene fossils have heretofore been recorded from Margarita.

CURAÇAO

In the Wagner Institute papers Dall recorded a number of Bowden pelecypods from Curaçao, a Dutch island lying off the Venezuelan coast. A footnote was added to Publication 366 (p. 25) calling attention to a probable error in this record. The so-called Curaçao material was originally scattered through a general collection. When it was assembled it became apparent that not only all the species are Bowden species, but the specimens have all the appearance of Bowden shells. Twenty-seven species are represented in this material, but it hardly seems worth while to list them, as all the determinable ones are Bowden species.

Dr. J. E. Benedict, of the United States National Museum, who was the naturalist on the Fish Commission steamer "Albatross" in 1884 when the Curaçao fossils were collected, informs me that locality labels were printed on board ship and were put with the collections. None of these labels is with the Bowden species, but a collection, consisting principally of large specimens of *Spondylus echinatus* Martyn, which has one of these labels, finally was found. These fossils were collected from one of the elevated Quaternary reefs. The record of Miocene fossils from Curaçao clearly is spurious. This result agrees with accounts of the geology and palaeontology of Curaçao (Martin, Bericht über eine Reise nach Niederländisch West-Indien und darauf

gegründete Studien, pt. 2, Geologie, 238 pp., 2 pls., 4 maps, 40 figs., Leiden, 1888; J. Lorié, Fossile Mollusken von Curaçao, Aruba, und der Küste von Venezuela: Samml. Geol. Reichs-Mus. Leiden, ser. 2, vol. 1, pp. 111-149, 2 pls., 1889; Vaughan, Some fossil corals from the elevated reefs of Curaçao, Aruba and Bonaire: Samml. Geol. Reichs-Mus. Leiden, ser. 2, vol. 2, 91 pp., 1901).

TRINIDAD

The literature list for Trinidad is as follows:

Literature list, Trinidad

Guppy 1866a	Pilsbry and Sharp 1897-98	Sheldon 1917
Guppy 1867	Guppy 1908	Van Winkle 1919
Guppy 1873a	Guppy 1910	Maury 1925
Guppy 1874	Guppy 1911	Mansfield 1925
Guppy 1882	Guppy 1912	Harris 1926
Dall 1890-1903	Maury 1912	Hodson 1926
Guppy and Dall 1896	Guppy 1913	Palmer 1927

The most recent discussion of the Miocene deposits of Trinidad is in Waring's report (The geology of the Island of Trinidad, B. W. I.: Johns Hopkins University Studies in Geology, No. 7, 180 pp., 20 pls., 1926) and Maury's report (1925) is the most complete description of the Miocene mollusks.

The stratigraphy of the Miocene beds of Trinidad is very complex and the nomenclature is confused. More than 400 Miocene and Pliocene species of mollusks are already on record. As no original data on Trinidad geology can be offered here, no attempt will be made to discuss the Miocene deposits other than to point out those that seem to be of about the same age as the Bowden formation. According to Maury, the Bowden species given in table on page 84 are found in the Miocene and Pliocene beds of Trinidad.

"*Leda*" *peltella* Dall and *Corbula heterogena* Dall, two Bowden species, the occurrence of which in Trinidad is based only on Guppy's record, are not included in this list, nor are *Conus planiliratus* Sowerby, *Typhis alatus obesus* Gabb, and *Glycymeris jamaicensis* Dall, which are recorded by Maury (see Pub. 366, p. 211). Some of the other identifications, based on poor material, are open to question. On a strictly numerical basis the Bowden fauna seem to most closely resemble that of the Manzanilla beds or of the Springvale beds. Inasmuch as none of the Trinidad faunas agree in size or in facies with the Bowden fauna, a comparison on such a basis is unwarranted. About the only conclusion that can be reached is that there is nothing in Trinidad to compare with the Bowden fauna. Maury's correlation of the Brasso beds with the Gurabo formation is accepted. Therefore, despite the preceding list, the Bowden formation seems to be of about

the same age or a little younger than the Brasso beds. Although many of the Brasso species resemble those from Bowden, only one, based on a worn unfigured specimen, has been recorded as identical.

Bowden species reported from Trinidad

SPECIES	Lower Mio- cene	Middle Miocene		Upper Mio- cene	Plio- cene
	Machapoorie beds	Manzanilla beds	Brasso beds	Springvale beds	Matura beds
Gastropods:					
Conus stenostoma Sowerby.....				?	
Distorsio decussatus simillimus (Sowerby).....		×			
Malea camura Guppy.....	?				
Strombus bifrons Sowerby.....	×				
Vermicularia spirata (Philippi)....					×
Lemintina papulosa (Guppy).....		×		×	
Architectonica nobilis quadrise- riata (Sowerby).....		×			
Diodora alternata henekeni Maury					?
Pelecypods:					
"Arca" occidentalis Philippi.....				×	×
Barbatia domingensis (Lamarck)...					×
Anadara inaequilateralis (Guppy)..			×		
Amusium papyraceum Gabb.....		×			
Crassinella guppyi (Dall).....				×	
Chama involuta Guppy.....		×			
Cardium serratum Linné.....				×	
Strigilla pisiformis (Linné).....					×

TOBAGO

Guppy (1903) recorded under the name of "*Arca patricia* Sowerby" the large *grandis*-like *Senilia* found at many other localities in Miocene deposits. This species has not yet been recorded from Pliocene deposits, but it would not be safe to assume that it disappeared at the end of Miocene time everywhere in the Caribbean region. The Tobago deposits that carry this species probably are of Miocene age,⁶ but additional material is needed to confirm this age determination.

BRAZIL

Only three reports (White 1887, Maury 1925a, and Palmer's compilation of the veneroids) deal with Miocene mollusks from Brazil. The material described by White and Maury was collected at two localities in the State of Para immediately south of the mouth of the Amazon. Almost 250 species have been described or recorded from these two localities, but many of them are based on unrecognizable molds. These beds are undoubtedly of lower Miocene age, and Maury's correlation of them with the Chipola formation of Florida, which in turn is correlated with the Baitoa, Thomonde, and Quebradillas formations, seems fully justified. Despite the great distance between the West Indies and the localities in Brazil, and the location of the mouth of the Amazon between them, the Brazilian fossils are, as Maury points out, very similar to lower Miocene species from the West Indies. An even more striking feature is the similarity of the living West Indian and Brazilian mollusks. Inasmuch as the great volume of water discharged by the Amazon would be an effective barrier to the spread of littoral marine species, Dall (Proc. Washington Acad. Sci., vol. 3, p. 139, 1901; Bull. U. S. Fish Commission, 1900, vol. 1, p. 355, 1901) concludes that the distribution of the Recent species apparently took place before the Amazon discharged so much water. The same conclusion can be reached for the lower Miocene species. The distribution of the Recent species can be regarded as indirect evidence of the late date of the uplift of the Andes, for, as Professor Berry orally suggests, the present Amazon system, which is fed principally by the heavy precipitation on the eastern slope of the Andes, is a direct consequence of that event.

At one of the Brazilian localities (Rio Pirabas) the lower Miocene beds carry *Orthaulax brasiliensis* Maury, which needs comparison with the West Indian lower Miocene *O. aguadillensis* Maury. *Clementia brasiliensis* Maury may represent the small form of *C. dariena* (Conrad), found elsewhere in northern South America in lower Miocene deposits.

PACIFIC COAST

NORTHERN SOUTH AMERICA

PERU

It is not considered necessary to compare the Bowden mollusks with those from the Tertiary deposits of Argentina and Chile, for both these regions fall in a different faunal province and Miocene beds of the same age as the Bowden formation would carry a different fauna.

The literature list for Peru is as follows:

Literature list, Peru

Nelson 1870	Hanna and Israelsky 1925
Grzybowski 1899	Hodson 1926
Woods 1922	Palmer 1927
Spieker 1922	

Both d'Orbigny (Voyage dans l'Amérique Méridionale, Paléontologie, vol. 3, pt. 4, 188 pp., 22 pls. in vol. 8 [1847], 1842) and Gabb (Am. Jour. Conch., vol. 5, pp. 25-32, 1870; Jour. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 8, pp. 263-336, pls. 35-43, 1881) describe Mesozoic, Eocene, and Quaternary mollusks from Peru, but apparently none from the Miocene beds.

The Miocene mollusks so far recorded from Peru are from the Zorritos formation in the extreme northern coastal part of the country. Spieker divides this formation into three parts. He records six species as identical with Bowden species (*Conus multiliratus* Gaza Johnson and Pilsbry, "*Dolium*" (*Malea*) *camura* (Guppy), "*Pitaria* (*Lamelliconcha*)" *planivieta* (Guppy) *Chione* (*Lirophora*) *hendersonii* Dall, *Tellina* (*Eurytellina*) *aequicincta* Spieker, and *Tellina* (*Angulus*) *pressa* Dall), but it is doubtful whether any of these species are represented at both localities. The relationships of the Zorritos mollusks are to be looked for in the Gatun formation of the Canal Zone and in the Miocene deposits of Colombia, Venezuela, and Darien. The presence of *Turritella* "*robusta*" Grzybowski, *T. bifastigata* Nelson, and a *Turritella* of the group of *T. altilira* Conrad, and of the Pacific genera *Aphera*, *Malea*, and *Clementia* gives the Zorritos fauna a familiar aspect in terms of Caribbean Miocene faunas, but "*Phos* ?" *latirugatus* Spieker, "*Argobuccinum*" *zorritense* Nelson, and *Triumphis solida* (Nelson) show that this fauna represents a different province. The Zorritos fauna as a whole has a middle Miocene appearance, the same as the Gatun formation. Iddings and Olsson (Bull. Am. Assoc. Petroleum Geologists, vol. 12, pp. 24-26, 1928), following Spieker, consider the Zorritos formation of lower Miocene age.

ECUADOR

Clementia dariena (Conrad) (Woodring 1926, p. 35) is the only Miocene mollusk so far recorded from Ecuador.¹ This species was listed from a locality in the Santa Elena Peninsula from beds that were called lower (?) Miocene. *Turritella* "*robusta*" Grzybowski and probably several other Zorritos species are in the same collection and in collections from near-by localities. These Miocene beds of the Santa Elena Peninsula probably are of middle Miocene age, like the Zorritos formation.

CENTRAL AMERICA

PANAMA

Very little has been published on the Miocene deposits of the Pacific coast of Panama, the only reports being as follows:

Literature list, Pacific coast of Panama

Dall 1890-1903

Woodring 1926

Joukowsky and Clerc 1906

Palmer 1927

¹A list was published recently by Sheppard (Notes on the Miocene of Ecuador: Bull. Am. Assoc. Petroleum Geologists, vol. 12, pp. 671-673, 1928).

Two of these reports (Dall and Woodring) deal with only one species—*Clementia dariena* (Conrad).

The deposits near Garachiné, in Darien, described by Joukowsky, may be of Miocene age, but more probably are Pliocene. The oyster recorded as "*Ostrea haitensis* Sowerby" belongs to the group of *O. megodon* Hanley.

Extensive collections from Darien were made by Dr. Axel A. Olsson and Dr. Frank Reeves on Rio Chucunaque and Rio Tuyra, and on tributaries of both these streams. Apparently these rivers flow in an extensive basin of Miocene deposits. Unfortunately it seems that either during shipment or during unpacking the collections from Darien were mixed with collections from localities near Mt. Hope or Mindi in the Canal Zone. Some of the collections now bearing a locality number for Darien look like straight Canal Zone collections, others seem to be a mixture, but others can be accepted as Darien material. Even the last collections have a number of characteristic Gatun species. *Conus molis* Brown and Pilsbry, a *Cancellaria* like *C. solida* Sowerby, "*Phos*" *gatunensis* Toulou, *Solenosteira dalli* Brown and Pilsbry, and "*Arca*" *dariensis* Brown and Pilsbry are easily recognized ones. A spiny *Cancellaria*, a *Xancus*, a new *Cymia*, several queer *Phos*-like species, *Turritella* "*robusta*" Grzybowski, and a number of brackish-water species including a *grandis*-like *Senilia* are not found in the Gatun formation. Most of these species give a more pronounced Pacific aspect to the Darien fauna, but the *Xancus* is the only fossil or living species from the eastern Pacific. The correlation of the Darien Miocene beds with the Gatun formation is as certain as correlation between two different basins ever can be. The presence of the Gatun species is sufficient evidence to assume that a transisthmian strait connected the Atlantic and Pacific during middle Miocene time. Additional evidence for this assumption is furnished by the statement of Maack (in Selfridge, Reports of explorations and surveys to ascertain the practicability of a ship-canal between the Atlantic and Pacific Oceans by the way of the Isthmus of Darien, p. 163, Washington, 1874) to the effect that the fossil-bearing beds of the Tuyra Valley extend across the continental divide into the basin of Rio Atrato. These Miocene Darien species have not yet gotten into the literature unless Palmer's record (1927) of three veneroids from the "Province of Darien" refers to them.

Miocene fossils have also been collected farther west in Panama, west of the Canal Zone. Joukowsky and Clerc described seven species from localities near Macaracas, in the Province of Los Santos. One of these species is a *Turritella* (*T. venezuelana* Hodson, ? = *T. tristis* Brown and Pilsbry), erroneously identified as *T. gatunensis* Conrad. These beds near Macaracas probably are of lower Miocene age. Other species, including a *Turritella* of the *altilira* group, are represented in

the United States National Museum in collections made near Macaracas and also in the Province of Herrera between Pesé and Océ. These lower Miocene beds also crop out in the vicinity of Santiago, where they carry small specimens of *Clementia dariena* (Conrad), and farther south in the Province of Veraguas along streams draining into the Gulf of Montijo. Collections from localities near Tolé, San Felix, and David, in Chiriqui Province, show that the lower Miocene beds have an extensive distribution along the Pacific coast of western Panama. Most of the material is poorly preserved, but it is estimated that close to 100 species are represented in the collections of the United States National Museum.

Less deformed beds near David carry an unmistakable Gatun fauna, which is remarkably distinct and can be traced on the Caribbean side from Costa Rica to Colombia and on the Pacific side from Darien to Chiriqui. A collection from Rio Platanar (U. S. G. S. station 7955) carries "*Drillia*" *gatumensis* Toulal, *Turritella gatumensis* Conrad, *Turritella "robusta"* Grzybowski, and possibly other Gatun or Darien species. At other places a relatively small *Senilia* is abundant. Both the lower and middle Miocene deposits of the Pacific coast of Panama carry *Clementia dariena* (Conrad) (see Woodring 1926, pp. 35-36).

COSTA RICA

Clementia dariena Conrad (see Woodring 1926, p. 36) and seven other species listed by Romanes (Quart. Jour. Geol. Soc. London, vol. 68, p. 125, 1912) are the only Miocene mollusks recorded from the Pacific coast of Costa Rica. Material in the United States National Museum, collected at Carballo cliff and Carballo tunnel, is rather poorly preserved, but it undoubtedly is Miocene, and it seems to be of the same age as the lower Miocene beds of Panama. The same beds, which consist almost entirely of volcanic débris, crop out at Brazil, west of San José, and farther inland at Santa Maria de Dota, which lies near the east edge of the Province of San José. Here again they carry *Clementia dariena* (Woodring 1926, p. 36, identification doubtful). A *Turritella* of the *altilira* group in the Alfaro collection from Narajo, five kilometers south of Turrúcares, still farther east, and external molds from tuff at Turrúcares probably were collected from beds of the same age. These isolated outcrops, separated by later floods of lava and tuff, indicate an extensive transgression of the lower Miocene sea and the presence of a transcontinental strait across central Costa Rica during lower Miocene time, as several writers have pointed out (for references see Woodring 1926, p. 28). The lower Miocene beds of the Pacific coast and interior of Costa Rica and Gabb's Sapote locality seem to represent the same age. *Schizaster cristatus* Jackson (U. S. Nat. Mus. Bull. 103, pp. 113-114, pl. 52, figs. 2-4, 1919), from

Brazil, needs comparison with *Schizaster scherzeri* Gabb (Jour. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 8, p. 348, pl. 45, figs. 28, 28a, b, 1881), from Sapote.

The limestones at Patarra, San Antonio de Desamparados, and San Miguel, described by Hill (Bull. Mus. Comp. Zool. Harvard College, vol. 28 (geol. ser., vol. 3), pp. 226-227, 1898), Alfaro (Bol. de Fomento, year 1, pp. 123-131, 5 figs., 1911), and Romanes (Quart. Jour. Geol. Soc. London, vol. 68, pp. 106-108, 1912) probably are older, but the Alfaro collection contains only fragmentary molds of a large and a medium-sized "*Pecten*" from these localities. This material, however, substantiates Romanes' view that these limestones are not Cretaceous, as they were called by Hill.

NICARAGUA

No Miocene mollusks from the Pacific coast of Nicaragua are on record, but a small lot of poorly preserved material, collected from the "Brito formation" by Hayes 75 miles northwest of Brito Harbor (U. S. G. S. station 6409), contains at least one species (a *Cyclinella*) that is also found in the lower Miocene beds near Puntarenas, Costa Rica, and other species in the lot have a Miocene aspect. Apparently the lower Miocene beds of the Pacific coast of Panama and Costa Rica extend at least as far northwestward as the middle of Nicaragua. This material confirms Vaughan's statement (U. S. Nat. Mus. Bull. 103, pp. 197, 591, 1919), based on Bassler's determination of a bryozoan, that Hayes included beds of both Eocene and Miocene age in the Brito formation.

Other material from Nicaragua, labeled Granada (U. S. G. S. station 3094), which lies on Lake Nicaragua, consisting principally of giant specimens of *Malea*, *Ostrea*, *Chione*, and *Harvella*, is Pliocene or Quaternary.

The only material from the Machuca formation of eastern Nicaragua, which Hayes considered of about the same age as the Brito formation, consists of molds of a fresh-water gastropod, probably *Hemisinus*.

OTHER AMERICAN LOCALITIES

ATLANTIC COAST

FLORIDA

The Florida Miocene section is as follows:

Florida Miocene deposits

Time subdivision	Formation	
Upper Miocene	Choctawhatchee marl	
Middle Miocene	Alum Bluff group	Shoal River formation Oak Grove sand ¹
		Chipola formation
Lower Miocene	Tampa and Chattahoochee formations	

¹ Gardner (Bull. Geol. Soc. America, vol. 35, pp. 861-862, 1924) considers the Oak Grove sand lower Miocene.

Dall has described the mollusks of the Tampa formation (U. S. Nat. Mus. Bull. 90, 1915), but many of the figures in this report are based on specimens from the Alum Bluff group. Whether these species are represented in the Tampa formation needs confirmation (see Gardner, Bull. Geol. Soc. America, vol. 35, pp. 858-859, 1924). The Chattahoochee formation is not so fossiliferous as the Tampa. Both these formations are considered as representing about the same horizon as the Anguilla formation. They are so much older than the Bowden formation that further discussion of them is unnecessary. Tampa records of *Spondylus bostrychites* Guppy, *Cardium bowdenense* Dall, and "*Gastrochaena*" *rotunda* Dall, all of which are Bowden species, are rejected or questioned in Publication 366.

The mollusks of the Alum Bluff group have been monographed by Dr. Julia Gardner, whose report is in course of publication, four parts, dealing with most of the pelecypods, having already been issued (U. S. Geol. Survey Prof. Paper 142-A, B, C, D, 184 pp., 28 pls., 1926). The deposits of the Alum Bluff group and the general character of their faunas are briefly described in the introduction to Gardner's report. The three formations of the group are not known to lie one above the other in any section, and their stratigraphic relations have been determined primarily by the fossils they carry. Detailed comparisons with the Bowden fauna must await the issue of the remainder of Gardner's report.

The Chipola formation carries almost 450 species of mollusks, according to Gardner (p. 2), a number that is far larger than the number found in either the Oak Grove sand or in the Shoal River formation. The Chipola fauna is subtropical and is much more like the Miocene faunas of tropical America than any other Florida Miocene fauna. Only a few of the genera are not found in the Miocene deposits of tropical America. The Chipola formation carries the last species of *Orthaulax* (*O. gabbi* Dall) known in the United States, and also the last species of *Alveinus* (*A. rotundus* Dall). It has a remarkable Eocene survivor in "*Ampullina*" *fischeri* Dall, which represents the genus *Globularia*. The Thomonde and Baitoa formations also carry *Orthaulax* and *Alveinus*, and it is expected that many other Thomonde and Baitoa species will be found to be similar to Chipola ones and that a number of species will be found in all three formations. The correlation of the Chipola, Tuxpan, Thomonde, and Baitoa formations, and Quebradillas limestone with each other is more definite than any other Miocene correlation between the Caribbean region and continental America.

Orthaulax has been mentioned so often in this discussion that it is natural to conclude that particular significance is attached to it. No more significance is given to it, however, than to any other widespread, easily recognized, and short-lived genus. The dangers of relying too much on the range of one genus are fully recognized. At one time *Orthaulax* was considered evidence of Oligocene age. According to current age assignments, however, it ranges from middle Oligocene to the top of the lower Miocene. Throughout tropical America and Florida it is not found in beds younger than the Thomonde, Baitoa, and Chipola formations, and the Quebradillas limestone. Other lines of evidence point to the essential synchronicity of these deposits, so that *Orthaulax* has turned out to be particularly valuable. Nagao (Japanese Jour. Geology and Geography, vol. 3, No. 1, pp. 13-18, pl. 1, 1924) has described a Japanese Eocene mollusk as *Orthaulax japonicus*. According to some of the figures (4a, 4c), the inner and outer lips of this species are not stromboid. It probably represents a genus of some other family that developed an *Orthaulax*-like habit of enveloping the spire and depositing callus between the whorls.¹

The Oak Grove sand carries less than half as many species as the Chipola formation (Gardner, p. 2). The presence of large busyconoids, an *Astarte*, and a *Lyropecten*, similar to species from the Chesapeake embayment, and the absence of some of the Chipola genera indicate water of slightly lower temperature. The Shoal River formation, which has a slightly larger fauna, carries three species of *Astarte*, but the presence of several genera of Cancellarias, of *Echino-*

¹ Since this was written Dr. Nagao kindly sent me two paratypes that confirm the suspicion that this species represents some other genus, probably allied to *Pseudoliva*.

chama, and of other tropical groups shows that perhaps the water was not cooler than during Oak Grove time. When descriptions of the Alum Bluff mollusks are available it will be found that the Shoal River mollusks are similar to those from the middle Miocene of Mexico and the Gatun formation of Costa Rica and Panama, due allowance being made for the difference in temperature facies (see Gardner, Bull. Geol. Soc. America, vol. 35, p. 862, 1924).

In this report and in Publication 366 only three Bowden species are recorded from the Chipola formation—*Volvula oxytata* Bush, *Rissoina browniana* d'Orbigny, and *Typhis alatus obesus* Gabb,—two of which represent smooth forms under which more than one species may be placed. None is recorded from the Oak Grove and Shoal River formations, the latter of which apparently is of almost the same age as the Bowden formation. Similarities for Oak Grove and Shoal River species are to be looked for in Mexico and to a less extent in Central America rather than in the West Indies.

The Florida Miocene beds are particularly interesting because they are the first ones so far discussed in which remains of land mammals have been found. These remains were described by Sellards (Florida Geol. Survey Eighth Ann. Rept., pp. 82–92, 1916). They were collected from a part of the Alum Bluff group that is correlated with the Chipola formation. At the time when they were discovered it was customary, following Dall, to consider the Alum Bluff “formation,” as it was then called, Oligocene. Sellards concluded from the presence of a horse of the genus *Merychippus* that it is Miocene. Vaughan (U. S. Nat. Mus. Bull. 103, p. 220, 1919) quotes Merriam's opinion that the *Merychippus* is of lower Miocene (Burdigalian) age.

The Choctawhatchee marl unconformably overlies the Alum Bluff group. Dr. W. C. Mansfield is now engaged on a monographic study of the mollusks of the Choctawhatchee formation and also of other Florida upper Miocene deposits. His work is showing some interesting results, a discussion of which must await the completion of his report. Dall (Trans. Wagner Inst. Philadelphia, vol. 3, pt. 6, p. 1594, 1903) has emphasized the pronounced faunal change in some of the upper Miocene beds leading to the widespread appearance of genera and species from the Chesapeake embayment. It is not expected that any Bowden species will be found in the upper Miocene beds, except a few Recent ones, but Mansfield has discovered that some of the Florida species need comparison with those from Costa Rica, and some of the Costa Rican beds may eventually be correlated with the Florida upper Miocene.

Both the Alum Bluff group and the upper Miocene beds carry Chiones belonging to the group represented by *C. burnsii* Dall (Chipola formation), *C. glyptocyma* Dall (Oak Grove sand), *C. trimeris* Gardner (Shoal River formation), and *C. ulocyma* Dall (upper Miocene). Some

of these species are very similar to *C. mactropsis* (Conrad), one of the characteristic species of the Gatun formation and of its equivalents in Mexico, Costa Rica, and Colombia. This species has not been found in the West Indies and furnishes another example of the distinctness of the Mexico-Central America-northern South America Miocene fauna from the West Indian one. This group of Chiones, which is going under the subgeneric name of *Lirophora*, deserves a name. Like many other Miocene groups from the Caribbean region and Florida it is no longer living there, but is represented in the Panamic and Mazatlantic regions by *C. kelletii* (Hinds).

So far as numbers of identical species are concerned the Bowden formation is more like the Pliocene Caloosahatchee marl than like any of the Florida Miocene beds. The following Bowden species are recorded by Dall from the Caloosahatchee marl:

Bowden species recorded from Caloosahatchee marl

Gastropods:

Volvula oxytata Bush
Conus proteus Hwass
Trivia pediculus (Linné)
Rissoina browniana d'Orbigny
Cheilea "equis" (Linné)"
Tectonatica pusilla (Say)
Murex pomum Gmelin

Pelecypods:

"*Arca*" *occidentalis* Philippi
Barbatia domingensis (Lamarck)
Cardium medium Linné
Cardium serratum Linné

It will be observed that all these are Recent West Indian species, and that none of the striking species characteristic of the Caloosahatchee marl is found at Bowden. So far as the Florida Miocene and Pliocene beds are concerned a numerical comparison with the Bowden fauna breaks down, for it is quite clear that the Bowden formation is not Pliocene, as the percentage of Recent species is far too low. The subtropical facies of the Caloosahatchee fauna and its greater size overbalance the age advantages that the Florida Miocene beds have.

MIDDLE ATLANTIC STATES

The Miocene deposits of the middle Atlantic States are as follows:

Miocene deposits of middle Atlantic States

Time subdivision	Formation
Upper Miocene	Duplin marl Yorktown formation
Middle Miocene	St. Marys formation Choptank formation Calvert formation

The correlation of the Calvert formation with the Tortonian of Europe is based on both plants and marine mammals (Berry, U. S. Geol. Survey Prof. Paper 98-F, 1916; Kellogg, Bull. Geo. Soc. America, vol. 35, pp. 763-764, 1924). According to the conclusion here reached as to the age of the Bowden formation, it is of about the same age as the Calvert, Choptank, or St. Marys formation. The Bowden mollusks are so different from those of any of these deposits that they might as well come from some other part of the earth. *Cardium medium* Linné is recorded from the St. Marys and Duplin formations and *Volvula oxytata* Bush from the Duplin. Both these Recent species are found at Bowden. Not only is there such a great difference in species, but many of the Bowden genera are not found in the middle Atlantic Miocene. According to published accounts, the following Bowden genera are recorded from the Duplin marl, but not from any of the others:

Bowden genera recorded from Duplin marl, but not from Calvert, Choptank, St. Marys, and Yorktown formations

Ficus ¹	Triphora	Fossularca
Cypraea	Rissoina	Placunanomia
Trivia	Naticarius	Echinochama

¹"*Pyrula*" *harrisi* Martin (Maryland Geol. Survey, Miocene, p. 226, pl. 55, fig. 3, 1904), from the Calvert formation, is not regarded as representing *Ficus*.

On account of its warmer facies the Duplin fauna is more similar to the Bowden fauna than any of the other Miocene faunas of Maryland, Virginia, and North Carolina.

PACIFIC COAST

LOWER CALIFORNIA

I have not found any record of Miocene deposits in the 2000-mile stretch between central Nicaragua and the southern part of the Peninsula of Lower California, where recent expeditions have discovered Eocene and Miocene beds (N. H. Darton, Geologic reconnaissance in Baja California: Jour. Geology, vol. 29, pp. 720-748, 22 figs., 1921. Arnold Heim, Notes on the Tertiary of southern Lower California: Geol. Mag., vol. 59, pp. 529-547, pls. 21-22, 7 figs., 1922. Anonymous, Informe sobre la exploración de la Baja California, par la "Marland Oil Company of Mexico": Bol. Petroleo, vol. 17, No. 6, pp. 417-453, pls. 4-46, map, 1924; vol. 18, No. 1, pp. 14-53, pls. 77-92, map, 1924). Darton's paper contains preliminary lists of the Miocene fossils collected. A list, based on specimens collected by Heim, was issued by Dickerson (Bull. Geol. Soc. America, vol. 28, pp. 230-232, 1917; Proc. California Acad. Sci., ser. 4, vol. 7, No. 8, pp. 197-205, 1917), and by Arnold and Clark (Bull. Geol. Soc. America, vol. 28, pp. 223-224, 1917). Descriptions of species, based for the most part

on the Marland collections, were recently issued by Hertlein and by Hertlein and Jordan (Proc. California Acad. Sci., ser. 4, vol. 14, No. 1, pp. 1-35, pls. 1-6, 1925; Proc. California Acad. Sci., ser. 4, vol. 16, No. 19, pp. 605-647, pls. 17-21, 1927).

The collections made by Darton, some of the material collected by the Marland expedition, and duplicates of the Heim collection are in the National collections. On the basis of this material it seems probable that both the lower and middle Miocene of Central America are represented in southern Lower California. Heim's material from Purisima, San Ramon, and La Huerta Vieja, containing the species identified by Dickerson as *Turritella tristis* Brown and Pilsbry, *Pecten oxygonum optimum* Brown and Pilsbry, and *Pecten condylomatus* Dall, would be called lower Miocene in Central America. "*Pecten oxygonum optimum*" probably represents *Chlamys canalis* (Brown and Pilsbry), from the Emperador limestone of the Panama Canal Zone. The specimens identified as "*Pecten*" *condylomatus* Dall closely resemble that species, which is found in the Chipola and Tuxpan formations, though they are considerably larger and for the most part less inflated. Neither of these Pectens is represented in the material described by Hertlein.

Heim's material that is considered middle Miocene was collected at Agua Verde and east of San Isidro. The Agua Verde collection contains Dickerson's "*Raeta gibbosa* Gabb" (probably *Raeta gardnerae* Spieker, the type of which is from the Zorritos formation of Peru), a mold of a *Chione*, a mold of a mactroid (probably a large *Mulinia* like *M. pallida* (Broderip and Sowerby)), and molds of a *Turritella*. The material collected east of San Isidro consists of a *Turritella* of the phylum of *T. ocoyana* Conrad, and an oyster like the Caribbean Miocene *O. haitensis* Sowerby, of which *O. gatunensis* Brown and Pilsbry may be a synonym, and also like *O. fischeri* Dall, now living in the Gulf of California. A Marland collection from a locality near San Ignacio (L. C. 7), containing *Turritella bösei* Hertlein and Jordan and *Cymia heimi* Hertlein and Jordan, in particular resembles the middle Miocene of Central America. A subspecies of *Cymia heimi*, or a species of the same phylum, is found in the middle Miocene beds of Darien that clearly are of the same age as the Gatun formation of the Panama Canal Zone (see p. 87). It represents a different phylum from the one embracing *C. henekeni* Maury of the Baitoa and Thomonde formations. *Turritella bösei* is the species repeatedly referred to in this discussion as *T. "robusta"* Grzybowski. The type material of *T. "robusta"* Grzybowski is from the Zorritos formation of Peru. It differs from *ocoyana*, as Spieker (Johns Hopkins Univ. Studies in Geology No. 3, pp. 85, 86, 1922) has pointed out, principally in its larger size and in having a sharper keel and heavier spiral threads. *T. robusta* Grzybowski (1899) is a homonym of

T. robusta Gabb (1864) and the Peruvian form will take the name of *Turritella abrupta* Spieker. Inasmuch as *T. "robusta" abrupta* Spieker and *T. charana* Spieker are considered synonyms of *T. "robusta,"* *T. supraconcava* Hanna and Israelsky (Proc. California Acad. Sci., ser. 4, vol. 14, No. 2, p. 59, 1925) is a quite unnecessary substitute name for "*robusta*." *T. robusta fredeai* Hodson (Bull. Am. Paleontology, vol. 11, pp. 183-184, 1926), based on material from Venezuela, and finally *T. bösei* Hertlein and Jordan are considered further synonyms. Though specimens from different localities and also from the same locality, even in the type region of *ocoyana*, differ in the prominence of the keel and in the strength and spacing of the spiral threads, and though it may be desirable to recognize the Lower California specimens as a subspecies, apparently six names have already been proposed for this tropical representative of *ocoyana*. *T. wittichi* Hertlein and Jordan probably represents the keelless variety of this phylum of Turritellas. Other species than those already mentioned are similar to Caribbean Miocene fossils. *Cypraea amandusi* Hertlein and Jordan is remarkably similar to *C. henekeni* Sowerby, found in the Gurabo and Gatun formations, and may turn out to be a synonym, or at least a subspecies, of *henekeni*.

Hertlein and Jordan consider that their material represents approximately the same horizon, which they correlate with the lower part of the Temblor formation of California. In accordance with the general practice of recognizing only two major Miocene divisions on the Pacific coast, they place this horizon in the lower Miocene, though it falls in the middle Miocene according to the nomenclature used in this discussion.¹

Vaughan (cited by Heim) has already called attention to the strategic importance of these Miocene fossils from Lower California. Like the Miocene fossils of the Isthmus of Tehuantepec on the Caribbean side they are in a critical place to furnish a means for comparing the deposits of tropical America with those of the United States. With these Mexican localities it should be possible to complete a correlation circuit from Florida to California by way of Central America. The correlation of the Miocene beds on the Atlantic side of Panama and Costa Rica with the deposits on the Pacific side of these countries seems to be on a firm basis. The fossils should, however, be described and an effort should be made to find additional Miocene outcrops

¹ Wiedey (Notes on the Vaqueros and Temblor formations of the California Miocene with descriptions of new species: Trans. San Diego Soc. Nat. Hist., vol. 5, No. 10, pp. 95-182, pls. 9-21, 1928) discusses the affinities of *T. bösei* in a paper that appeared as the proof of this report was being read. He proposes to use *bösei* for the keeled Turritellas found in California and Lower California, and *ocoyana* for those that are not keeled. This arrangement is unsatisfactory, for keeled and unkeeled specimens, which are similar in other features, are found at the same locality. Hertlein and Jordan, for example, record *bösei*, *ocoyana*, and *wittichi* from the same locality.

between Lower California and Nicaragua. What has been said concerning the Miocene fossils of Lower California also applies to the Eocene ones. Some of the Eocene beds, which probably represent an upper Eocene zone, carry *Velates* and giant *Cerithia*. With the *Velates*-bearing upper Eocene beds of Chiriqui Province, Panama, and the middle Eocene beds of Los Santos Province, Panama, they offer an attractive field for comparing the Eocene of tropical America and California.

CALIFORNIA

According to Clark (Bernice P. Bishop Mus. Special Pub. 7, table op. p. 804, 1921; Jour. Geology, vol. 29, table op. p. 586, 1921), the standard Miocene section for the California Coast Ranges, slightly modified to admit a middle Miocene division, is as follows:

Standard Miocene section, California Coast Ranges (after Clark)

Time subdivision	Formation	
Upper Miocene	San Pablo group ¹	Santa Margarita formation Cierbo formation (San Pablo formation of U. S. Geological Survey) Briones formation
Middle Miocene	Temblor ¹ [and Topanga] formation. (<i>Turritella ocoyana</i> zone)	
Lower Miocene	Vaqueros formation. (<i>Turritella inezana</i> zone)	

¹ Not recognized by U. S. Geological Survey.

A direct comparison of the Bowden and California Miocene faunas is naturally more impracticable than a comparison with the Miocene fossils of the Chesapeake embayment. Perhaps a working correlation can be reached, however, by utilizing the Lower California and Central American localities. Unfortunately only the upper Miocene California faunas have so far been monographed. The Temblor fauna probably offers the most promising field for comparison with Lower California and Central America. According to Smith (Proc. California Acad. Sci., ser. 4, vol. 3, p. 165, 1912), the "Monterey-Temblor fauna" consists of about 154 species, and Anderson and Martin (Proc. California Acad. Sci., ser. 4, vol. 4, pp. 41-44, 1914) list 89 species from the Temblor formation of the Kern River region, which has yielded the best material. Smith (Proc. California Acad. Sci., ser. 4, vol. 9, p. 160, 1919) considers the "Monterey-Temblor fauna" tropical or subtropical, but it is not tropical either in terms of the

Recent Panamic fauna or in terms of the Caribbean Miocene faunas. The type locality of *Turritella ocoyana* Conrad falls in the Kern River region. This species is the guide fossil of the Temblor formation, or *Turritella ocoyana* zone, according to Merriam's designation (California Univ. Dept. Geol. Bull., vol. 3, pp. 377-381, 1904; Trans. Am. Philos. Soc., n. s., vol. 22, pp. 14-16, 1915). It has already been pointed out that *Turritellas* of the phylum of *T. ocoyana* are found in Lower California in beds that are considered of middle Miocene age, and that *T. abrupta* Spieker ("robusta" Grzybowski) represents the same phylum. Perhaps *T. abrupta* should be considered a subspecies of *ocoyana*, but its disposal must await comparisons with large suites of specimens from California and Lower California. Specimens of *ocoyana* from Southern California (Santa Monica and Santa Ana Mountains) generally are keeled, whereas only a small proportion of those from the type region in the Kern River region are keeled. The specimens from Southern California seem to be intermediate between the *ocoyana* of Central California and the large sharply keeled *abrupta* of tropical America.

In this discussion the tropical form of *ocoyana* is recorded from the Santa Rosa beds of the Isthmus of Tehuantepec, from Colombia and Venezuela, all on the Caribbean side; and from Peru, Darien, Chiriqui Province, Panama, and Lower California, on the Pacific side. It will be observed that the beds carrying *Turritellas* of the *ocoyana* phylum have on independent grounds been referred to the middle Miocene, except those in Venezuela for which no data are available. On the Caribbean side this *Turritella* is found in two middle Miocene zones corresponding to the Cercado and Gurabo formations of the Dominican Republic. No predecessor of *ocoyana* has been found in California, and it seems probable that the phylum reached the Pacific from the Atlantic, where it may have developed from a stock represented by *T. subgrundifera* Dall of the Chipola lower Miocene.

By means of this indirect comparison and relying for the most part on the admittedly slender evidence of one phylum of *Turritellas* it is concluded that the Bowden formation is of about the same age as the Temblor formation, or as the upper part of the Temblor formation. Additional material for testing this conclusion is available in the Lower California collections. Merriam's (Trans. Am. Philos. Soc., n. s., vol. 22, pp. 4-6, 14-26, 1915) conclusion that land mammals found in the Coalinga region in beds that are referred to the upper part of the Temblor formation represent a middle Miocene horizon, furnishes additional, though indirect, evidence as to the middle Miocene age of the deposits in Lower California and on the Pacific coast of Panama that are the equivalent of the Gatun formation of the Panama Canal Zone. Kellogg also has recorded marine pelagic mammals from the Temblor formation of the Kern River region,

which he considers is Helvetian (California University Bull. Dept. Geol. Sci., vol. 13, No. 4, pp. 23-132, 6 figs., 1922; Carnegie Inst. Washington Pub. 346, art. 2, 24 pp., 9 pls., 1927). So far mammals have been found in the Miocene beds under discussion only at the extreme ends of the correlation circuit—in Florida and California. It is to be hoped that they will be found at intermediate localities. In the two regions where they have been found the evidence that they furnish is in agreement with the evidence based on the mollusks.

EUROPE

For purposes of comparison with the Bowden formation the Miocene deposits of the North German, Aquitaine, and Piedmont Basins are taken as representative of the principal geographic divisions of the European marine Miocene.

NORTH GERMAN BASIN

A detailed comparison of the Bowden and German faunas is no more practicable than a comparison with localities in the Chesapeake embayment and California. Inasmuch as the German Basin was an extension of the present North Sea, it would not be supposed that the deposits there represent a warmer facies than any in the Chesapeake embayment. Yet according to the early reports by von Koenen (Schriften-Gesell. Beförderung gesammten Naturwiss. Marburg, vol. 10, pp. 137-262, 3 pls., 1872; Neues Jahrb., Beil.-Bd. 2, pp. 223-367, pls. 5-7, 1883) they carry "*Ancillaria*," "*Pyrula*" (= *Galeodes*), "*Phos*," "*Turbinella*" (= *Latirus*), and *Mathilda*, none of which is found in the Chesapeake embayment, as well as "*Ficula*," *Cypraea*, and *Trivia*, which occur in the Duplin marl, but not in the other Chesapeake formations. Kautsky (Abh. Preussischen Geol. Landesanstalt, n. s., No. 97, 255 pp., 12 pls., 1925) also records *Liotia* and *Triphora*, both of which in the Chesapeake embayment are found only in the Duplin marl. In terms of American faunas, however, the German Miocene would still be warm temperate. The Chesapeake Miocene offers the most promising field for direct comparison (see Dall, Maryland Geol. Survey, Miocene, pp. cl-cliii, 1904). The German Miocene includes lower, middle, and upper Miocene, but the principal fossiliferous beds (Holstein beds) generally are placed in the middle Miocene.

AQUITAINE BASIN

The type localities of the Aquitanian and Burdigalian stages lie in the Aquitaine Basin in southwestern France. As the part of the monograph by Cossmann and Peyrot on the Aquitaine mollusks dealing with the gastropods is incomplete, the comparison with the Bowden fauna is limited to the pelecypods. The Aquitaine faunas

are warm temperate to subtropical and should be compared with the Florida Miocene rather than with the Caribbean Miocene. The percentage of Bowden genera and of Recent species furnishes about the only basis for comparison. As a warning it should be stated that generic comparisons have not yet reached a reliable stage, for large collections from Aquitaine have not been examined. Some of the generic determinations in an earlier comparison probably are incorrect (Woodring, Bull. Geol. Soc. America, vol. 35, pp. 867-886, 4 figs., 1924).

The approximate percentage of Bowden genera and of Recent species is graphically shown in fig. 3. The time spacing in this graph is arbitrary. Data for the percentage of Recent species are taken

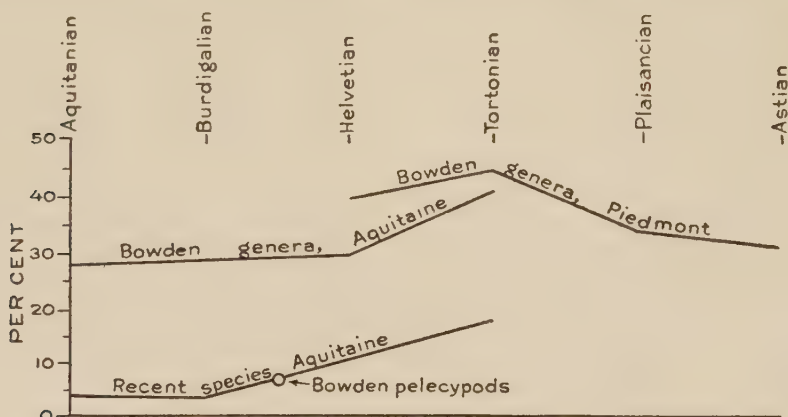


FIG. 3.—Graph showing approximate percentage of Bowden genera and of Recent species in Miocene faunas of Aquitaine Basin, and approximate percentage of Bowden genera in Miocene and Pliocene faunas of Piedmont Basin (based on pelecypods).

from Cossmann and Peyrot (Conch. Néog. Aquitaine, vol. 2, pt. 1 (Actes Soc. Lin. Bordeaux, vol. 66), p. 483, 1912). According to the number of genera in common the Bowden fauna is most like that of the Tortonian, whereas according to the percentage of Recent species it would fall between Burdigalian and Helvetian. Even if there were no question as to the identity of genera, such a numerical comparison is not to be taken too seriously, for it disregards too many factors. The Tortonian fauna is only a third as large as the others. The Bowden and Aquitaine faunas differ at least in temperature facies, and different workers have determined the percentage of Recent species. The percentage of Bowden genera may also be a function of facies and not of time.

The Chipola fauna of Florida offers perhaps the most promising field for direct comparison with the Aquitaine faunas. The Aquitanian and Burdigalian, like the Chipola formation, carry a strange Eocene survivor in the genus *Globularia* ("*Ampullaria*" *compressa* Basterot),

and they also carry an "*Amauropsis*" ("*Natica*" *eburnoides* Grateloup) like "*A.*" *burnsii* Dall, from the Chipola formation, and "*A.*" *burnsii meridionalis* Pilsbry, from an unknown horizon, probably the Baitoa formation, in the Dominican Republic. These two genera at least suggest that the Chipola formation falls in the first half of the Aquitaine marine series, though in the Piedmont basin *Globularia* survived until the Helvetian stage.

The only European species of *Noetia*, "*Arca (Anadara)*" *okeni* Mayer, is found in the Aquitanian and Burdigalian of Aquitaine and in the Helvetian of Touraine. This genus has not been recorded from Bowden or any other Miocene locality in the West Indies proper, but it is very abundant in Central America, northern South America, and Trinidad, 10 species having already been described. If long-continued residence and abundance of species mean anything *Noetia* is autochthonous in American waters, yet "*Arca (Anadara)*" *molengraaffi* Martin (Samml. Geol. Reichs-Mus. Leiden, n. s., vol. 2, No. 5, p. 184, pl. 7, figs. 191, 191a-b, 192, 192a, 1915), from the upper Eocene of Nanggulan, Java, has all the features of *Noetia*. Nevertheless, the isolated occurrence of only one species in Europe in beds as old as Aquitanian indicates that it reached Europe from America, where it is also found in the Chesapeake Miocene. Inasmuch as the earliest species so far recorded from America comes from the Manzanilla beds of Trinidad, which are placed in the lower part of the middle Miocene, *Noetia* should turn up in American beds at least as old as the Anguilla and Tampa formations, unless the age assignments of the American deposits is wrong by at least two stages. According to available information, *Noetia* reached the Caribbean region from the Pacific, and it should be looked for in the California Eocene or Oligocene.

No definite conclusions can be drawn at present from a comparison with the Aquitaine stages, though the Bowden fauna falls somewhere in the latter half of the Aquitaine series and the Chipola formation seems to fall in the first half, which agrees with current age assignments.

PIEDMONT BASIN

The type localities of the Langhian, Tortonian, Plaisancian, and Astian stages lie in the Piedmont Basin, so that the Aquitaine and Piedmont Basins together contain the type localities of six Miocene and Pliocene stages. The Helvetian of the Piedmont Basin may also be regarded as typical of the stage that goes under that name in the Mediterranean region. The earlier numbers of the great series of monographs by Bellardi and Sacco on the Piedmont mollusks dealing with some of the gastropods are out of date as to nomenclature. For this reason and also so as to afford a basis for comparison with the Aquitaine Basin, the numerical comparison with the Bowden fauna is

limited to the pelecypods. As before, these comparisons are based for the most part on illustrations.

The approximate percentage of Bowden genera in the Piedmont faunas is graphically shown in fig. 3. Assuming that the Helvetian and Tortonian stages of the Piedmont and Aquitaine Basins represent the same time interval, a comparison of the graphs shows rather clearly that the percentage of Bowden genera is at least in part a function of climatic facies. The Piedmont faunas, at least the Miocene ones, are more tropical, and therefore the percentage of Bowden genera is larger. The presence of temperate and boreal genera ("*Chrysodomus*," *Astarte*, and *Macoma*) indicates, however, that the Piedmont faunas are not quite tropical in the same sense as the Bowden fauna, though they represent a much warmer facies than the Chesapeake Miocene, which lies 10° farther south. So far as temperature facies is concerned they most closely resemble the Mexican Miocene. The percentage of Bowden pelecypod genera in the Chesapeake Miocene does not run over about 34 in any of the beds, so that on the basis of comparing genera the Bowden fossils are more like those from the other side of the Atlantic than like those from the middle Atlantic coast, as Guppy recognized long ago (Quart. Jour. Geol. Soc. London, vol. 22, pp. 282, 285, 1866).

The presence of a great many genera—among them *Ancilla*, *Uromitra*, "*Turbinella*," "*Phos*," "*Thiarella*" (= *Metulella*), *Metula*, *Distorsio*, *Bursa*, *Sconsia*, *Malea*, *Ficus*, *Strombus*, "*Terebralia*" (= *Clava* in part), *Cheilea*, "*Perna*" (= *Pedalion*), *Amusium*, *Codakia*, *Linga*, and *Cardiolucina*,—all of which are found in the Bowden formation and all of which are exotics so far as present European seas are concerned, give the Piedmont fossils a familiar appearance in terms of those from Bowden. The resemblance between many of the species is so striking that the American specimens will have to be compared with the European ones. The similarity is particularly close in some families—Arcidae, Lucinidae, Marginellidae, Pyrenidae, Cymatiidae, Bursidae, Cassididae,—whereas in others most of the genera are different—Veneridae and Trochidae.

The maximum number of Bowden genera falls in the Helvetian, but the largest percentage falls in the Tortonian. For Bowden and other West Indian Miocene genera together the maximum percentage falls in the Helvetian (see Woodring, Bull. Geol. Soc. America, vol. 35, p. 885, fig. 4, 1924). Though the degree of similarity to the Bowden fauna has some facies significance, it is concluded from the number of common genera and of similar species in the Helvetian and Tortonian and from the percentage of Recent species in the Bowden formation that the Bowden fauna falls in the middle Miocene. I have several times gone on record as considering it Helvetian in terms of the Mediterranean Miocene (see Bull. Geol. Soc. America, vol. 35, pp.

881-884, 1924). I think that the evidence now available fails to warrant an attempt to make correlations across the Atlantic as fine as one stage. In shifting the American Miocene column the Bowden formation is now placed opposite the Tortonian, but that does not mean that it has been shown that it is Tortonian, as the graphs can not be accepted as representing age alone. If an European stage name must be used it seems better to use Vindobonian, a name that was proposed by Depéret for the Second Mediterranean stage of Suess minus the Pontian.

What significance is to be attached to the presence of so many genera in both the Miocene Mediterranean and Caribbean Seas and to their absence farther north in Europe and America during Miocene and earlier periods also must remain open. I have lent support to the idea that these shallow-water genera must have had shallow water to get across the Atlantic (Bull. Geol. Soc. America, vol. 35, pp. 425-436, 1924). This faunal similarity might also be cited in support of the Wegener hypothesis of continental drift. Probably not enough is known about the length of pelagic larval stages, and the distance larvae can be carried by currents to warrant such sweeping palaeogeographic conclusions. It seems reasonable to believe that the larval stage of gastropods that have a large "nucleus" consisting of many whorls, such as the frog-shells, tritons, and tuns, lasts long enough to permit transportation under favorable conditions across the Atlantic in the track of the south equatorial current. At all events some of the Recent species are even more widely distributed in the tropics. Perhaps the families that are represented by many identical genera on the two sides of the Miocene Atlantic are the ones that have a long larval stage, and the ones that are represented by endemic genera have a short stage or none at all. The assembling of available information on larval stages and the obtaining of additional data are the most urgent needs in the study of the distribution of Tertiary mollusks.

THE ORIENT

It is going rather far afield to compare a West Indian Miocene fauna with one from the Orient. A certain amount of similarity would be expected, for both regions are in the tropics, and the Recent West Indian and Oriental faunas have many genera in common and many pairs of analogous species. The Miocene faunas of the two regions are bound to be more similar on account of the Pacific exotics in the West Indian Miocene. Yet the similarity of the Miocene faunas goes even farther, for some of the Oriental Miocene and earlier Tertiary genera that are found in the West Indian Miocene are no longer living in the Orient. Attention has already been called (p. 101) to *Noelia*, which appears in the Javanese upper Eocene. Martin (Samml. Geol. Reichs-Mus. Leiden, n. s., vol. 1, pp. 158-159, pl. 24, figs. 336, 336a, 337, 337a, 1895) records from the Javanese Miocene

and Pliocene a *Sconsia* for which he uses the name given to a living West Indian species. At the present time *Sconsia* is confined to the West Indian region. According to available records it is found in the Oligocene of southern United States, the Mediterranean region, Sind, and Burma, and in the Miocene of the West Indian and Mediterranean regions, so that the Javanese species seems to be a survivor from an invasion from the Mediterranean. Vredenburg (Rec. Geol. Survey India, vol. 51, p. 95, 1921¹) also considers *Cypraea murisimilis* Martin a synonym of *C. henekeni* Sowerby from the Gurabo and Gatun formations. In his first paper on the Indian Tertiary species of "*Turbinella*" Vredenburg recorded there the phylum of *Xancus ovoidea* (Kiener), which is now living on the coast of Brazil, and proposed the name "*Turbinella*" *praeovoidea* for a species from the upper Gaj (lower Miocene) of Sind (Mem. Indian Mus., vol. 6, p. 123, 1916). Later on discovering that the Indian fossils represent a different phylum the name was changed to *praemekranica*² (Rec. Geol. Survey India, vol. 55, pp. 119-128, 1923; Mem. Geol. Survey India, vol. 50, pt. 1, pp. 174-177, 1925). This genus also is first found in the Oligocene of southern United States, the West Indian region, and the Mediterranean region, and Vredenburg records the Mediterranean Oligocene species from the Nari series (Oligocene) of Sind. It lived in the Mediterranean Sea until Pliocene time and during middle Miocene time gained a temporary footing in the eastern Pacific as a migrant from the Caribbean. It is now living in both the West Indian and Oriental regions.

Data are not now available for a detailed comparison of the Bowden and Oriental Miocene faunas. According to Martin's monographs the Conidae, Marginellidae, Mitridae, and Pyrenidae of Java and the genera *Metula*, *Cassis*, *Sconsia*, and *Malea* have a particularly familiar appearance in terms of Bowden fossils.

No particular palaeogeographic significance can be attached to this resemblance, and it seems that the age determination of the Oriental Miocene deposits must rest on comparison with Europe without any essential aid from tropical America. It has been supposed that the Mediterranean Sea and Indian Ocean were no longer in communication after Eocene time (see discussion by Vaughan, Bernice P. Bishop Special Pub. No. 7, pp. 866-873, 1921), but the work by Vredenburg on the post-Eocene mollusks of northwest India, cut short by his

¹ I am unable to understand why Vredenburg (p. 112) proposed a new name, *C. antillarum*, for the Miocene Dominican species described by Gabb as *C. spurca* Linné, for he could have no idea of what Gabb had. Pilsbry (Proc. Acad. Nat. Sci. Philadelphia, vol. 73, p. 365, 1922) accepts *spurca* as a Dominican fossil, without, however, citing Gabb's record. Apparently *C. antillarum* Vredenburg is a synonym of *C. spurca* Linné.

² According to a strict adherence to the rules of the Code, Vredenburg could not withdraw his earlier name, for it was far from a *nomen nudum*. However unfortunate the result may be, apparently the Gaj species will have to be known as *X. praeovoideus* (Vredenburg) and *X. praeovoideus* Maury (Bull. Am. Paleontology, vol. 5, pp. 247-248, 1917; *praeovoideus* by error, see errata), which really is a predecessor of *ovoidea*, will have to have a new name.

lamented death, conclusively shows that the Nari series (Oligocene) carries a large number of Mediterranean Oligocene species, and that the characteristic European Miocene species "*Melongena*" *cornuta* (Agassiz) and "*M.*" *lainei* (Basterot) are found in the overlying Gaj series (lower Miocene). Vredenburg (Mem. Geol. Survey India, vol. 50, pt. 1 pp. 3-5, 1925) concludes that the Mediterranean Sea and Indian Ocean were in free communication during at least part of Oligocene time, and that imperfect communication continued during lower Miocene time. It has already been pointed out that the occurrence of *Clementia*, *Placuna*, and other genera in the Miocene Mediterranean Sea indicates a temporary invasion of Oriental mollusks into the Mediterranean (Woodring, U. S. Geol. Survey Prof. Paper 147, p. 29, 1926).¹ The Oligocene and Miocene section of northwest India, the age of which is now well established in terms of Mediterranean deposits, offers the best basis for establishing the correlation of the Miocene beds of the East Indies and other parts of the Orient. According to Vredenburg, the Gaj series closely corresponds to the part of the Miocene section in Java that Martin on independent grounds referred to the lower Miocene.

PERCENTAGE OF LIVING SPECIES

Percentage of living species, used with due caution, still is the fundamental basis for determining the age of a late Tertiary fauna, no matter how much it has gone out of fashion. In this report and in Publication 366 the following Recent species are recorded from the Bowden formation:

Recent species in Bowden fauna

Gastropods:

Cavolina telemus (Linné)
Volvula oxytata Bush
Conus proteus Hwass
Conus planiliratus Sowerby²
Murex recurvirostris Broderip
Murex pomum Gmelin
Trivia globosa ("Gray") Sowerby
Trivia pediculus (Linné)
Vermicularia spirata (Philippi)
Spirolaxis exquisita (Dall and Simpson)
Rissoina browniana d'Orbigny
Cheilea "equestris" (Linné)³
Tectonatica pusilla (Say)
Tricolia umbilicata (d'Orbigny)

Pelecypods:

"*Arca*" *occidentalis* Philippi
Barbatia domingensis (Lamarck)
Fossularca adamsi (Dall)
Chlamys nodosus (Linné)⁴
Chama macerophylla Gmelin
Diplodonta gabbi Dall⁵
Cardium medium Linné
Cardium serratum Linné
Gouldia insularis (Dall and Simpson)
Chione granulata (Gmelin)⁶
Strigilla pisiformis (Linné)

¹ For a recent discussion see Cox (Pal. Zanzibar Protectorate, pp. 15-16, 1927).

² *C. simpsoni* Dall probably is a synonym of this species.

³ The subspecific name *sawkinsi* used in Publication 366 is suppressed.

⁴ Not recorded in Publication 366.

⁵ Recent specimens are recorded under name of *D. puncturella* Dall, which is a synonym.

⁶ Not recorded in Publication 366.

It seems only fair to include also the forms that are considered subspecies of living species, for they fall within the same specific limits. It probably is apparent in the systematic account that the subspecific lines are finely drawn, except with very variable species. In accepting some of the subspecies I also may have been unwittingly influenced by the availability of a name, if one already were in use. Larger suites of specimens may show that others of the subspecific names are unwarranted. It will be seen that only one pelecypod is in this list, which is another indication that the pelecypods are over-named. The following are recorded as subspecies of Recent species:

Subspecies of Recent species in Bowden fauna

Gastropods:

Oliva reticularis trochala Woodring
Latirus infundibulum polius Woodring
Mitrella ocellata bowdenensis Woodring
Distorsio decussatus simillimus (Sowerby)
Distorsio clathratus gatunensis (Toula)
Sconsia striata sublaevigata (Guppy)
Cypraea isabella patrespatriae Maury
Modulus modulus basileus (Guppy)
Architectonica nobilis quadriseriata (Sowerby)
Architectonica krebsii lampra Woodring
Natica canrena antinacca Cossmann
Polinices brunnea subclausa (Sowerby)
Sigatica semisulcata bathyora Woodring
Astraea brevispina basilis (Olsson)
Homalopoma philipiana oedamata Woodring
Smaragdia viridis viridemaris (Maury)
Calliostoma pulcher bowdenense Woodring
Microgaza rotella vetula Woodring
Lucapina limatula vetula Woodring
Diodora alternata henekeni (Maury)

Pelecypods:

"Arca" umbonata morantensis Woodring

According to these lists 25 Recent species and 21 subspecies of Recent species are recorded, making a total of 46, or about $9\frac{1}{2}$ per cent of the 485 named species. This is only a little more than half of the original figure of about 17 per cent for the Miocene given by Lyell and Deshayes (Lyell, *Principles of Geology*, vol. 3, p. 54, 1833). It would be simple, however, to pick out 50 additional species that are so similar to Recent ones that they would have been considered the same in their generation; in fact 13 species now considered distinct from living ones were recorded by Guppy as Recent species. The percentage for the Bowden fauna is not far from Dall's early estimate of 12 per cent (*Trans. Wagner Inst. Philadelphia*, vol. 3, pt. 6, p.

1581, 1903). The percentage for some other Miocene deposits is as follows:

Percentage of Recent species in other Miocene beds

	Per cent
Calvert, Choptank, and St. Marys formations, Maryland.....	10 ¹
Calvert formation, Maryland.....	9.3 ²
Choptank formation, Maryland.....	11.4 ²
St. Marys formation, Maryland.....	12.1 ²
St. Marys formation, Virginia.....	18 ³
Yorktown formation, Virginia.....	17 ²
	25 ³
Duplin marl, North Carolina.....	20 ²
	27 ³
Helvetian, Aquitaine (pelecypods only).....	10.7 ⁴
Tortonian, Aquitaine (pelecypods only).....	18.8 ⁴
Middle Miocene, Hemmoor, Germany.....	16 ⁵
First Mediterranean stage, Eggenburg, Austria.....	28 ⁶

It is expected that additional Bowden species will be found living in the West Indies, for little intensive dredging has been done there in water of moderate depths. One haul in Porto Rican waters is the only Recent record for *Spirolaxis exquisita* (Dall and Simpson) and four hauls in the same region have furnished the only Recent specimens of *Gouldia insularis* (Dall and Simpson), both of which are found at Bowden. *Diplodonta "puncturella"* Dall is represented from only three localities—Porto Rico, St. Thomas, and Jamaica. In addition the dredgings of the *Fish Hawk* in Porto Rican waters have furnished *Terebra guanica* Dall and Simpson, "*Cythara*" *asarca* Dall and Simpson, and "*Phos*" *oxyglyptus* Dall and Simpson, all of which are very similar to Bowden species.

One of the Recent species, *Murex recurvirostris* Broderip, is recorded as living on both the Atlantic and Pacific sides of Central America. Two others, *Mitrella ocellata bowdenensis* Woodring and *Architectonica nobilis quadriseriata* (Sowerby), fall within the specific limits of forms that are now living in both regions, though the *Mitrella* generally is given a different name. In considering the question as to the identity of living species in these two regions, the possibility of tracing lineages back to Miocene time when free intercommunication was possible, needs serious consideration.

Only three of the Recent species at Bowden—*Volvula oxytata* Bush, *Rissoina browniana* d'Orbigny, and *Tectonatica pusilla* (Say)—are

¹ W. H. Dall, Maryland Geol. Survey, Miocene, p. cxlvi, 1904.

² W. H. Dall, Maryland Geol. Survey, Miocene, p. cxlvii, 1904.

³ J. A. Gardner, cited by T. W. Vaughan, Bull. Am. Assoc. Petroleum Geologists, vol. 7, p. 521, 1923.

⁴ M. Cossmann and A. Peyrot, Conch. Néog. Aquitaine, vol. 2, pt. 1, p. 483, 1912.

⁵ F. Kautsky, Abh. Preussischen Geol. Landesanstalt, No. 97, p. 223, 1925.

⁶ F. X. Schaffer, Sitzungsber. K. Akad. Wiss., Math.-Nat. Cl., vol. 119, pt. 1, p. 251, 1910; vol. 121, pt. 1, p. 334, 1912.

smooth, whereas some of the others, such as the two species of *Murex*, have very elaborate sculpture. It is apparent that each species must be considered on its merits and that no particular stratigraphic reliance can be placed on elaborately sculptured species.

CONCLUSIONS AS TO AGE

On the basis of percentage of living species and in terms of the standard European section the Bowden fauna is Miocene, and the evidence seems to warrant considering it middle Miocene (Vindobonian). In terms of the American section it falls at the top of the middle Miocene or at the base of the upper Miocene.

These conclusions do not materially alter the age assignment made by Guppy, the pioneer in the study of West Indian Tertiary mollusks, more than half a century ago. The similarity to the Miocene of southern France and the Mediterranean region is too striking to have been missed by a palaeontologist trained in Europe. So far as relative place in the American section is concerned these conclusions also do not differ very much, aside from differences in nomenclature, from Dall's opinion that the Bowden formation probably is the equivalent of the Oak Grove sand or falls somewhere between the Chipola and Choctawhatchee formations (Trans. Wagner Inst. Philadelphia, vol. 3, pt. 6, p. 1582, 1903). Dall's conclusion that the Miocene of the early workers in the West Indian region is Oligocene (Proc. U. S. Nat. Mus., vol. 19, pp. 303-304, 1896; Trans. Wagner Inst. Philadelphia, vol. 3, pt. 6, pp. 1580-1581, 1903), based solely on a misapprehension as to the age of some of the beds in the Aquitaine Basin, influenced American nomenclature for twenty years or more. My early conclusion that the Bowden fauna probably is Burdigalian (Johns Hopkins Univ. Circular, n. s., 1917, No. 3, p. 56, 1917) need not be considered seriously.

VITA

Wendell Phillips Woodring was born in Reading, Pennsylvania, June 13, 1891. He attended Albright College and in 1910 received there the degree of Bachelor of Arts. After two years of high-school instruction he began graduate work in geology at the Johns Hopkins University. The field seasons of 1913-16 were spent with field parties of the United States Geological Survey in Colorado, Utah, Wyoming, and Montana.

